A two headed Death Adder. See paper on page 73.

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## Volume 31 No 1

## HERPETOLOGICAL NOTES

# EDITORIAL

Volume 31 of Herpetofauna marks the end of an era, as well as the beginning of a new millenium. After more than 29 years at the helm, Gerry Swan has requested a break, retiring as editor of Herpetofauna. The earliest issues of the journal were strangely reticent about the identity of the editor or editors. However, in volume 4(4), published in February 1972, Gerry was mentioned as one of two members of the editorial committee (the other member being Jack Verhagen). It was not until two years and seven issues later that the identity of the editorial committee was again formally listed, and Gerry was still there, with Hal Cogger and David Millar. From the time when responsibility for the journal was transferred from the Australian Herpetological Society to the Australasian Affiliation of Herpetological Societies with volume 8(2), in August 1976, Gerry has been the sole editor of the journal.

During his period as editor, Gerry has overseen growth and improvement in many ways. Initially a roneoed newsletter-style publication with a variable number of issues per volume, Gerry saw it changed to a formally printed journal appearing with two parts per volume (volume 6). A further standardisation of one volume per year, with the two issues appearing at the middle and end of the year (now June and December), was realised with volume 17, in 1987.

Volume 6 saw the introduction of photographs on the front cover. Volume 9(2) saw the introduction of colour covers, although the photographs were still monochrome. The journal changed from matt to glossy paper with volume 12 in 1980, introduced colour photographs on the cover with volume 20(2) in 1990, and added back cover photographs in volume 25, in 1995.

The size of the journal has slowly increased since it began appearing with two issues per volume. Volumes 6-9 had a total of 52 or fewer pages. Volumes 10 and 11 broke the 60 page limit. Volume 12 reached 76 pages.

Volume 14, the first of several volumes with the two issues under the one cover, reached 100 pages, although for a few years there was a decline, with the minimum of 32 pages reached with Volume 17. Since volume 25, Herpetofauna has consistently had more than 100 pages per volume. A separate section for herpetological notes first appeared in volume 10(1), and has continued.

Gerry has also overseen a gradual increase in the geographic coverage of the journal. Original articles in early volumes of Herpetofauna were based on observations in the three eastern Australian mainland states, as befitted a society based in New South Wales. The first paper on a Western Australian topic appeared in 1974, on the Northern Territory in 1975, on South Australia in 1976 with the formation of the Affiliation, and most recently, on Tasmanian species in 1988. The first original papers on non-Australian topics occurred in 1978, with volume 10(1) including papers from the Solomon Islands and New Zealand, while Fijian and Papua New Guinean species entered the journal in 1983 in volume 14.

On behalf of the Australasian Affiliation of Herpetological Societies, its member societies, and particularly the Australian Herpetological Society, I thank Gerry for his stewardship of the journal over the past three decades. Few journals have had the benefit of such a consistent guiding hand.

In taking over as editor, I will be seeking to further improve the quality of the journal, while still maintaining the critical balance between amateur and professional herpetological interests. In particular, the policy statement that appeared in the first "Notes to contributors" in 1976, "Herpetofauna publishes original articles on any aspect of reptiles and amphibians.... encouragement is given to articles reporting field work and observations", and that has continued since, will continue to guide me.

# PREY SELECTION IN THE AUSTRALIAN SCINCID LIZARD
## *CRYPTOBLEPHARUS VIRGATUS*

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## INTRODUCTION

In the literature on Australian lizards and snakes, there are a number of claims that a particular species is a specialist on a particular type of prey (e.g., Pianka, 1986). These claims are usually based on the observation of a large number of a particular type of prey in the stomach contents of the predator. The problem with this deduction is that the availability of the prey to the predator is not known. Are termites the predominant prey in the stomachs of a particular lizard species because these lizards actively selected this prey type from a wide range of equally accessible potential prey types? Or do these lizards eat almost anything they can capture and swallow, such as termites which just happened to be particularly common at the time of the lizards' last feeding, say on a warm humid evening just after termites had swarmed? In terms of the jargon of hypothesis testing, what evidence is there in any of these claims of prey selectivity to refute the null hypothesis that the predator species is simply eating the kind of prey in the same frequency at which it is actually available to the predator?

There are two ways of approaching the problem of prey selectivity: field observation and experimentation. This note reports two serendipitous field observations of prey selection (including its converse, avoidance) in *Cryptoblepharus virgatus*, a small, diurnal, climbing skink common on the east and south coasts of Australia (Cogger, 2000).

## MATERIALS AND METHODS

The observations were made by one of us (AG) on several *Cryptoblepharus virgatus*

active around a low brick barbecue and the horizontal cylindrical timbers fencing an adjacent small garden in Hyams Beach, Jervis Bay, New South Wales. The observations were made intermittently between 1000 and 1200h in the period 1 to 5 February 2000. There was a total of seven skinks in the general area; four of the skinks were large adults and three were either large juveniles or small adults. Most of the observations were made on the east-facing wall of the barbecue. During the course of the morning, sunlight slowly moved down this wall, reaching the bottom at about 1030h and then extending across the surrounding cement patio. At the bottom of the wall were the entrances to two ant nests about 1.2 m apart. One entrance was slightly higher and larger, and more active (with workers) than the other. Worker ants collected at the higher, more active nest were subsequently identified as members of the *Iridomyrmex rufoniger* group. During the first part of the observation period, roughly between 1015 and 1030h, the skinks were generally active on the sunlit upper parts of the barbecue and adjacent timbers. However, when the sun extended to the entrances of the ant nests, the ants became active and the skinks spent more time around the nests. The activity of the ants diminished almost to the point of cessation around mid-day, perhaps because of high substrate temperatures.

## OBSERVATIONS

During the night of 1 February there was occasional heavy rain. The following morning was humid and partly cloudy. At about 1040h during a prolonged period of sunshine, one of us (AG) was casually watching the skinks on the upper part of the barbecue and adja-

cent timbers. Their activity consisted of basking with frequent changes of position. What was striking during this observation period was how the skinks were constantly avoiding the individual scurrying worker ants. If an ant approached them, even the largest skink moved away.

Shortly after the observation period began, a fine mist of rain fell for a few minutes despite the sunshine. Shortly thereafter, the skinks seemed to become more animated and moved in the direction of the ant nests, that is, to the east face of the barbecue. The ants were swarming in large numbers and among them were a few conspicuous alates (winged reproductive forms) from the higher nest. It was the alates that had apparently drawn the attention of the skinks.

The general behaviour of the alates was to emerge from the nest, and begin climbing rapidly upward until they reached the upper edge of the barbecue, where they would hesitate a moment or two and then fly away. The skinks were intent on catching and eating the alates which came steadily in small numbers. However, the skinks had two problems: catching the fast moving alates and avoiding the swarming workers. The skinks would wait on the outer edge of the swarming mass until they spotted an alate. Then they would run in, snatch the individual and dash out again to the periphery to consume it.

On subsequent days when there were no alates, and in what was probably their normal routine, the skinks spent a large amount of time in the vicinity of the entrances of the nests. They generally faced the entrances to the nests. Occasionally, a skink would dash directly to the mouth of the nest, look in quickly, and then instantly dash away. On one of these occasions, a skink seemed to come away with something in its mouth. The skinks also took an interest in the ant trails in the horizontal recesses formed between the courses of bricks.

On three occasions when the skinks were watching the activities of the ants around the nests, a passing pillbug ( Crustacea: Isopoda: Oniscidea) attracted the attention of a skink to the extent that the skink rushed toward the pillbug but only to stop a few centimetres away and resume its previous activity.

## DISCUSSION

In general, when the skinks were basking away from the ant nests, they assiduously moved out of the way of the worker ants, even single wandering individuals. Clearly, even a single worker warranted avoidance. However, as the ants became routinely active around the nest entrance, the skinks seemed to shift their attention to the ants' activity near the entrance and along the main trails to and from the entrance. It is not clear why the skinks were interested in the ants, but in that this species has been reported to stand just to one side of the trails and rob worker ants carrying provisions back to the nest (Greer, 1989), it is assumed that this was what attracted the skinks' attention and made up a major part of their routine at this time of day. However, despite this species of ant's almost certain omnivorous habits, the workers returning along the trails seemed to be largely empty-handed, and a skink was never observed in an act of theft, other than possibly on the single occasion when a skink seemed to take something from the very entrance to the upper nest.

In contrast to the skinks' active avoidance of workers, they were very intent on capturing and eating single alates, even when they were among a mass of workers. This is clear evidence of selectivity by the skinks for one form of this ant species over the other. But what was so attractive about the winged form?

In the group of *Iridomyrmex* species to which these ants belong, both male and female reproductives are winged. As none of the alates were collected, it is unknown whether only one or both sexes were emerging on the morning of the observations. In terms of mean percentage fat by dry weight, *Iridomyrmex purpureus* winged females have a higher fat content than either winged males

or workers, the mean percentage dry weight values being 47.2, and 9.6 and 18.8 , respectively (Griffiths and Simpson, 1966, as *I. detectus*). Although no statistical comparison was made, it is likely that the winged females had significantly higher fat content than winged males or workers, but whether the difference between the latter two forms was significant can not be determined. In general, the percentage fat in females, at least, is relatively high compared with other ants, termites and small invertebrates (Redford and Dorea, 1984). On this limited information, the skinks may have been interested in the alates – if they included females - due to their higher fat content.

However, there is another, and not necessarily mutually exclusive, reason the alates may have been attractive. If the alates of this species are like the alates of most other species of their genus, then they are likely to have been less defensively inclined, at least in terms of behaviour if not in armament. This explanation is especially attractive in view of the possibility that if some or all of the alates were male, their contained energy may have been less than, or at least not significantly different from, that of the workers (above).

For either of the above reasons, that is, higher energy content or less defensive capacity, the alates represented an obviously attractive prey item in comparison to the workers.

There is also clear evidence for selectivity in the behaviour of the skinks towards the pillbugs. The initial interest in, but subsequent turning away from, the three passing pillbugs suggests that the skinks, perhaps primed to take a potential prey item, took the crustaceans for possible prey, but then rejected them upon closer inspection. Whether, the skinks "recognised" the pillbugs by vomerolfaction or vision is unclear.

Many other Australian skinks, including other species of *Cryptoblepharus*, eat ants (Table 1). However, in only one case are there details as to the form of the ants eaten: the ants eaten by *Eulamprus quoyii* in the New England area

included only winged individuals of undetermined sex (Veron, 1969).

Several species of skinks eat large numbers of ants (Table 1). By volume of prey, the species with a percentage of ants > 15 are, in decreasing order: *Notoscincus ornatus* (100), *Egernia inornata* (38.9), *Eremiascincus richardsonii* (21.4) and *Lerista muelleri* (15.6). By number of prey items, the species with a percentage of ants > 50 are, in decreasing order: *Notoscincus ornatus* (100) and *Hemiergis decresiensis* (76). There is also the observation that in a sample of faeces of *Eulamprus tenuis* "over 90 % of the matter consisted of the remains of small ants — their heads were obvious under magnification" (Rankin, 1973). However, this sample may have been biased by the digestive process. Another "comprehensive series of faeces" contained no identifiable ant material (Rankin, 1973). Whether any of these skinks show an actual preference for ants remains to be determined.

Finally, the data on ant eating in skinks show just how variable ants are in the diets of individual species and therefore how prone to sampling error the interpretation of prey specialisation, or even bias, can be. For example, in some species, some studies found no ants in the stomachs but in other studies the proportion of ants was noteworthy, if not large, by volume: 8.3 percent in *Clairaescincus entrecasteauxii* and 21.4 percent in *Eremiascincus richardsonii* and by number: 16 percent in *Morethia boulengeri* (Table 1). Perhaps as in our study, it was all a matter of the availability of the right kind of ant.

Ants are an extremely diverse group of organisms with complex behaviours, physiologies and life histories. Hence it is almost certain that ants will vary both intra and interspecifically in their palatability to predators. We have shown here the importance of intraspecific variation in one ant species in its palatability to one lizard predator. Undoubtedly a more detailed study of the kinds of ants eaten by various lizards would reveal some interesting general patterns.

## ACKOWLEDGEMENTS.

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**Table 1. The percent of ants in the diets of Australian skinks. Data are for the percent of ants in the total diet by volume, number of individuals and mass, and the percent of the total number of lizards containing ants (all four variables based on the total number of specimens with any prey in stomach).**

| | Prey (Ants) | | | Predator (Skink) | | |
|---|---|---|---|---|---|---|
| Species | Vol. | No | Mass | Individs | N | Reference |
| Carinascincus ocellatus | - | - | - | 35.8 | 201 | Wapstra and Swain, 1996 |
| Clairaescincus entrecasteauxii | 8.3 | 14.6 | - | - | 212/213 | Brown, 1988 |
| | - | - | - | 3.6 | 28 | Webb, 1995 |
| Coeranoscincus reticulatus | 0 | 0 | 0 | 0 | 18 | McDonald, 1977 |
| Cryptoblepharus plagiocephalus | 6.3 | - | - | - | 104 | Pianka, 1986 |
| virgatus | - | 0 | - | - | 7 | Webb, 1983 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Ctenotus* | | | | | | |
| ariadnae | 1.4 | - | - | - | 16 | Pianka, 1986 |
| atlas | 0.4 | - | - | - | 25 | Pianka, 1986 |
| brooksi | 10.8 | - | - | - | 79 | Pianka, 1986 |
| calurus | 0.8 | - | - | - | 202 | Pianka, 1986 |
| colletti | 0 | - | - | - | 14 | Pianka, 1986 |
| dux | 5.5 | - | - | - | 186 | Pianka, 1986 |
| grandis | 0 | 0 | 0 | 0 | 4 | Smith, 1976 |
| | 1.4 | - | - | - | 105 | Pianka, 1986 |
| helenae | 1.1 | - | - | - | 134 | Pianka, 1986 |
| cf helenae | 0.4 | 3.4 | - | 14 | 73 | James, 1991 |
| leae | 4.3 | - | - | - | 22 | Pianka, 1986 |
| leonhardii | 1.2 | - | - | - | 116 | Pianka, 1986 |
| | 2.9 | 17.9 | - | 25 | 87 | James, 1991 |
| pantherinus | 0 | 0 | 0 | 0 | 26 | Smith, 1976 |
| | 0.6 | - | - | - | 134 | Pianka, 1986 |
| | 1.7 | 1.8 | - | 36 | 86 | James,1991 |
| piankai | 0 | 0 | 0 | 0 | 2 | Smith, 1976 |
| | 1.7 | - | - | - | 22 | Pianka, 1986 |
| | 1.3 | 11.4 | - | 8 | 50 | James, 1991 |
| quattuor- | 1.5 | - | - | - | 388 | Pianka, 1986 |
| decimlineatus | 0.8 | 2.6 | - | 12 | 212 | James, 1991 |
| robustus | - | - | - | 30 | 10 | Archer et al., 1990 |
| schomburgkii | 0.9 | - | - | - | 134 | Pianka, 1986 |
| taeniolatus | - | 5.9 | - | - | 18 | Webb, 1983 |
| | 0.70 | 28.2 | - | 14.3 | 105 | Taylor, 1986 |
| | - | - | - | 18.2 | 11 | Archer et al., 1990 |
| *Cyclodomorphus* | | | | | | |
| casuarinae | 0 | 0 | 0 | 0 | 12 | Shea, 1988 |
| melanops | 0 | 0 | 0 | 0 | 39 | Smith, 1976 (as Omolepida branchialis) |
| | 0.4 | - | - | - | 6 | Pianka, 1986 (as Omolepida branchialis) |
| michaeli | 0 | 0 | 0 | 0 | 10 | Shea, 1988 (as New South Wales C. casuarinae) |
| *Egernia* | | | | | | |
| cunninghami | - | - | - | 28.6 | 92 | Barwick, 1965 |
| depressa | 0.8 | - | - | - | 32 | Pianka, 1986 |
| kintorei | 5.0 | - | - | - | 1 | Pianka, 1986 |
| inornata | 38.9 | - | - | - | 124 | Pianka, 1986 |
| striata | 10.0 | - | - | - | 190 | Pianka, 1986 |
| striolata | - | 11.1 | - | 14.3 | 35 | Bustard, 1970 |
| *Eremiascincus* | | | | | | |
| fasciolatus | - | 25 | 5.1 | 19 | 52 | James and Losos, 1991 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *richardsoni* | 21.4 | - | - | - | 8 | Pianka, 1986 |
| | 12.3 | - | - | - | 42 | Henle, 1989 |
| | - | 20 | 3.4 | 27 | 45 | James and Losos, 1991 |
| *Eulamprus* | | | | | | |
| *heatwolei* | - | - | - | 0 | 60 | Webb, 1995 |
| *quoyii* | - | 78.4 | - | 33 | 59 | Veron, 1969 |
| | - | - | - | 5 | 50 | Daniels, 1987 |
| *tenuis* | - | 0 | - | - | 1 | Webb, 1983 |
| *Glaphyromorphus* | | | | | | |
| *isolepis* | 0 | 0 | 0 | 0 | 13 | Smith, 1976 |
| *Harrisoniascincus* | | | | | | |
| *coventryi* | 0 | 0 | 0 | 0 | 12 | Webb, 1995 |
| *Hemiergis* | | | | | | |
| *decresiensis* | - | 76 | - | 78 | 32 | Crome, 1981:fig. 2 |
| *Lampropholis* | | | | | | |
| *delicata* | - | - | - | 71 | 7 | Crome, 1981 |
| | - | 28.5 | - | - | 8 | Webb, 1983 |
| | - | 5.7 | - | - | 7 | Lunney et al., 1989 |
| *guichenoti* | - | 18 | - | 27 | 56 | Crome, 1981:fig. 1 |
| | - | 9.9 | - | - | 85 | Lunney et al., 1989 |
| *Lerista* | | | | | | |
| *bipes* | 0 | 0 | 0 | 0 | 15 | Smith, 1976 |
| | 1.7 | - | - | - | 92 | Pianka, 1986 |
| *bougainvillii* | 0 | 0 | 0 | 0 | 19 | Smyth and Smith, 1974 |
| | - | 2.5 | - | 4.9 | 82 | Barden and Shine, 1994 |
| *desertorum* | 0 | 0 | 0 | 0 | 8 | Pianka, 1986 |
| *ingrami* | 0 | 0 | 0 | 0 | 3 | Covacevich et al., 1997 |
| *muelleri* | 0 | 0 | 0 | 0 | 6 | Smith, 1976 |
| | 15.6 | - | - | - | 10 | Pianka, 1986 |
| *punctatovittata* | 2.7 | - | - | - | 80 | Henle, 1989 |
| *xanthura* | 15.4 | - | - | - | 11 | Henle, 1989 |
| *Lygisaurus* | | | | | | |
| *burnetti* | 0 | 0 | 0 | 0 | 7 | Webb, 1983 |
| *Menetia* | | | | | | |
| *greyii* | - | 10 | - | - | 44 | Smyth and Smith, 1974 |
| | 0 | - | - | - | 20 | Pianka, 1986 |
| *Morethia* | | | | | | |
| *boulengeri* | - | 16 | - | - | 80 | Smyth and Smith, 1974 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 0 | 0 | 0 | 3 | Crome, 1981 |
| *butleri* | 0 | - | - | - | 16 | Pianka, 1986 |
| *Nannoscincus maccoyi* | 0 | 0 | 0 | 0 | 12 | Webb, 1995 |
| *Notoscincus ornatus* | 100 | 100 | 100 | - | 9 | Smith, 1976 |
| *Pseudemoia spenceri* | 0.3 | 1.2 | - | 6.9 | 72 | Brown, 1986 |
| | - | - | - | 7.7 | 13 | Webb, 1995 |
| *Tiliqua multifasciata* | 1.4 | - | - | - | 3 | Pianka, 1986 |
| nigrolutea | <0.01 | <0.01 | <0.01 | 1 | 4 | Webb and Simpson, 1985 |
| | <0.01 | <0.01 | <0.01 | 1 | 3 | Webb, 1987 |
| *rugosa* | - | ~ 4 | - | - | 31 | Bamford, 1980 (see Shea, 1989 for other general references) |
| *scincoides* | 0 | 0 | 0 | 0 | 1 | Webb, 1983 |

# SIDEWINDING IN TERRESTRIAL AUSTRALIAN ELAPID SNAKES

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## INTRODUCTION

In lateral undulation or 'serpentine locomotion' by snakes and other limbless vertebrates, regular waves are formed anteriorly and travel back along the body and tail, with continuous and symmetrical alternation of lateral bends to the right and left. As they move, the horizontal bends push laterally outward and backward against the substrate, fixed obstacles, or a fluid medium such as water or grass (Gray, 1946; Gans, 1962; 1974; Jayne, 1986; Cundall, 1987). In sidewinding locomotion, the waves moving along the body consist of asymmetrical loops arching above the substrate to either the left or right of the body axis, and between successive waves each part of the body may be practically stationary for a brief interval, 'pushing' mainly downward. The independence of successive body waves is a resemblance to concertina locomotion, but some sidewinders run the waves together, eliminating the stationary intervals as in lateral undulation (Jayne, 1986). The reliance on near-vertical contact forces with the ground minimises slippage on smooth or shifting substrates. On a surface such as loose sand, sidewinding snakes leave characteristic tracks consisting of separated, nearly straight, parallel body impressions offset obliquely from each other, each with a 'hook' at one end formed by the head or neck aligned with the direction of travel. Even without confirmation by tracks or slow-motion image analysis, sidewinding can be recognised by its asymmetry, the arching or looping of the body off the substrate, and in many cases by the 'stop-start' motion of the head during otherwise continuous progression.

Sidewinding has been reported for snakes of various lineages, usually on 'shifting' (loose or slippery) substrates, and is most characteristic of diurnal viperine and crotaline viperids inhabiting open, sandy desert terrain. However, it has also been seen in amphibious homalopsine and natricine colubrids, a small boid (on wet mud), non-desert terrestrial colubrids (on substrates including hard open ground), and a terrestrial tropidophiid (Bogert, 1947; Cowles, 1956; Brain, 1960; Bustard, 1969; Jayne, 1986; and recent reviews by Greene, 1997; Greer, 1997; Heatwole and Abbott, 1998). Heatwole and Abbott (1998) report tracks as evidence for sidewinding by the marine amphibious elapid *Laticauda colubrina* (Banded Sea Krait) on dry beach sand, and the behaviour has also been observed directly (R. Shine, pers. comm.). There appear to have been no documented reports of the use of sidewinding locomotion by terrestrial elapid snakes, though it has been mentioned in *Acanthophis* (Greene, 1997). Here, I report sidewinding on artificial, non-shifting surfaces by several species of Australian terrestrial elapid snakes (species of *Suta, Parasuta, Cryptophis* and *Denisonia*), all of which are small, nocturnal members of the livebearing lineage identified by Shine (1985). Possible selective advantages for sidewinding in these snakes are suggested, using information on their habitats, morphology and other behaviours. Taxonomy here follows Greer (1997) and Keogh et al. (2000), and 'common' names are mostly from Ehmann (1992).

## OBSERVATIONS

I first observed sidewinding by a *Parasuta dwyeri* (Eastern Hooded Snake) from Moonie, Qld, in November 1978. On asking other herpetologists about the subject at the time, the only other instances I heard about concerned the same species from the New England plateau, NSW (R. Shine, pers.

comm.). Subsequently I tested snakes of various species on a short, coarse carpet and a smooth wooden table. On the carpet, all snakes were able to move adequately, if slowly, by lateral undulation, but some switched to sidewinding either spontaneously or when approached 'threateningly' by the observer. The same snakes also used sidewinding on the table, which was too slippery for effective lateral undulation. Species for which 'absence' is reported have been tested on at least one of the same surfaces. In most cases they used slow but effective concertina locomotion on the table, but when frightened performed vigorous lateral undulatory movements resulting in slow progress by 'slide-pushing' (Gans, 1985). Results for all elapid species tested are summarised in Table 1.

The moderately stout *Parasuta dwyeri* (Eastern Hooded Snake) and *Suta punctata* (Spotted Snake) have a rapid style of sidewinding in which the posterior body and tail appear to 'flick' against the substrate, reminiscent of the saltational escape locomotion of *Delma* spp. (Pygopodidae; e.g. Ehmann 1992). The same is true of *Cryptophis nigrostriatus* (Black-striped Snake), though the anterior part of the more elongate body forms more regular waves. In a terrarium, these three species usually burrowed into loose soil to rest, rather than using rocks or other loose cover. Two less elongate species of *Cryptophis* (*C. nigrescens*, Eastern Small-eyed Snake; *C. boschmai*, Eastern Carpentaria Snake) have shown no tendency to sidewind; they also shelter under rocks or logs rather than burrowing (Table 1).

The more robust *Denisonia devisii* (DeVis's Banded Snake) has a relatively slow and 'deliberate' sidewinding pace, at least as an adult. This was observed within hours after obtaining a specimen (from Bourke, NSW), so it is surprising that it has not been recorded previously. After the snake repeatedly refused skinks and frogs, and regurgitated after force-feeding attempts, I offered it a large *Oedura lesueurii* (Lesueur's Velvet Gecko) in

dim light. It immediately took the shrieking gecko by midbody, lifted it clear of the floor (the same short carpet) and proceeded to sidewind to a dark corner before feeding. Unlike the other 'sidewinders', *D. devisii* sheltered under rocks rather than soil. As observed by Savitzky (1983), underground sheltering or burrowing behaviour is highly correlated with the surface texture of dorsal scales; all 7 'fossorial' species in Table 1 (omitting *Suta suta* as behavioural data are incomplete) have highly glossed scales, while none of 17 non-fossors do ($x^2 = 24.0$, 2 d.f, p<0.001).

With most species, it is fairly clear whether sidewinding is occurring or not. However, *Vermicella annulata* (Eastern Bandy-Bandy) used lateral undulation or concertina when moving slowly, but when 'threatened' it responded with the stereotyped defensive display (e.g. Shine, 1991; 22). This display, with one or more lateral loops of the body held vertically off the substrate as stiff arches, has a certain resemblance to the 'rolling loops' of a sidewinder in extreme slow motion. However, actual sidewinding locomotion was not observed in this species.

H. Ehmann (pers. comm., 1999) records sidewinding in two additional species not covered by my own observations. In about 1970 he observed (and filmed) sidewinding by a hot and agitated adult *Acanthophis antarcticus* (Southern Death Adder): 'It was a recently captured SA coastal adult released to "perform" on a bare and rather warm dense, fine red sand dune about 400 km inland.' Ehmann (pers. comm.) also states that *Suta suta* (Curl Snake) sidewinds, 'at least big/fat/gravid ones'.

## DISCUSSION

### Adaptive value of sidewinding in elapids

First of all, it should be noted that sidewinding in Australian elapids can not be explained simply by identifying closely analogous instances in other taxa or continents, and assuming that the same mechanisms of

adaptation apply in each case. Except for *Suta punctata* and *S. suta* in parts of their ranges, none of the elapid 'sidewinders' (Table 1) are found in sandy deserts; none are amphibious (although parts of their range suffer occasional widespread flooding); and all are nocturnal, so the danger of overheating during locomotion (Cowles, 1956) is unlikely to be significant. They occupy a similarly wide range of habitats (sclerophyll forest, woodland, and hummock grassland, commonly associated with cracking clay soils), and feed nocturnally either by ambush or searching under cover (Shine, 1991; Ehmann, 1992).

The reports of sidewinding here are based on observation of snakes in disturbed conditions and on artificial surfaces, so do not necessarily mean that this is a frequent or normal mode of locomotion in more natural conditions. Lacking an obvious parallel in terms of habits and habitat with the viperid and colubrid examples, it is conceivable that the ability to sidewind in the elapids, rather than itself being adaptive, is a side-effect of some other locomotory adaptation (e.g. for burrowing into loose sand or soil, or entering or traversing vertical soil cracks). There is at most a weak association between fossoriality (in the sense of burrowing into the soil to rest, rather than the more specialised habit of constructing and inhabiting tunnels; cf. Bamford, 1998) and sidewinding; in a 2x2 contingency table with data from Table 1 the observed frequencies are: 3 sidewinding and fossorial, 2 sidewinding and non-fossorial, 4 non-sidewinding and fossorial, 15 neither sidewinding nor fossorial ($x^2 = 2.89$, 2 d.f, not significant). Some of the African viperine sidewinders (species of *Bitis* and *Cerastes*) also rest under loose sand during the day, but they 'shuffle' vertically into the substrate leaving the top of the head exposed (e.g. Spawls and Branch, 1995) rather than burying completely using ordinary, forward lateral undulation like the 'fossorial' elapids. No other 'regular' sidewinders are fossorial even to this extent, and none of the other snakes in which occasional sidewinding is

reported is predominantly a burrower. As for cracking clay soils, no sources indicate that any association with sidewinding occurs beyond Australia. Thus, since there is no known precedent or mechanism for sidewinding to occur as a 'spandrel' (Gould & Lewontin, 1979), I make the more parsimonious assumption that it is an adaptation, and seek an explanation in terms of possible advantages over other forms of locomotion in the habitats these species occupy.

Cowles (1956) rejected the 'widespread belief that the curious horizontal broadside movement of *Crotalus cerastes* known as "sidewinding" is a specific adaptation to locomotion on the sandy surfaces of the desert'. He noted that sidewinding is 'overwhelmingly associated with open terrain that is predominantly free of protruding vegetation or obstructing rocks,' and suggested the actual advantage was the ability to rapidly cross extensive areas of open ground between scattered patches suitable for foraging, or patches of shade during the heat of the day. Thus, we can consider at least two adaptive explanations for sidewinding, based on 'open terrain' and 'shifting substrates' respectively. These are not necessarily exhaustive, but - contrary to an assumption apparently made by Cowles - they are not mutually exclusive either.

As noted above, the elapid sidewinders occur in forest, woodland, and hummock grassland. These habitats are highly 'patchy', but the spaces between major items of cover or foraging sites - trees, logs, clumps of grass etc. - are not very great, typically no more than a few metres. In comparison to 'deserts' or tidal mud flats, 'open terrain' does not seem to describe these habitats very accurately, and on first sight it seems that Cowles' 'overwhelming association' breaks down in these cases. However, we need to consider the open spaces at the scale relevant for these small snakes, and also in terms of the risks or costs involved in crossing them by different forms of locomotion.

While small, nocturnal snakes are not at risk

of overheating during activity in the open, they are at increased risk from predators such as owls, frogmouths, and possibly also carnivorous mammals (the latter are also able to locate prey within refugia, so the increase in risk from this source may be relatively minor). The chance of detection by such predators will depend on audibility as well as (or more than) visibility, while vulnerability after detection will depend partly on distance from cover, and partly on the snake's speed and agility. Thus, crossing even relatively small expanses of open ground can represent a dangerous activity for small nocturnal snakes, and may impose selection for increased speed and reduced audibility.

In semi-arid regions of Australia, the extent of ground cover between major items of shelter (for the snakes and their prey) can vary greatly among years and seasons. At some times there are considerable expanses of exposed loose sand, compacted soil, or deeply cracked clay, which may present very different problems and opportunities for snake locomotion. However, a major feature of woodland and shrubland is a ground cover of leaf litter, forming patches below and close to source trees. When large or close together, these patches may coalesce into a continuous blanket. The spaces within and under the litter provide refugia for many snakes and their prey, especially lizards - see e.g. Ehmann's (1992) article on *Lerista* - but the surface can be described as a 'shifting substrate'. Such a substrate is relatively homogeneous, and also much less dense and (when loose and dry) less resilient than either desert sand or wet mud.

On dry leaf litter, relatively long- or heavy-bodied snakes can efficiently use lateral undulation or concertina between sparse, fixed objects such as roots, tussocks, fallen branches, or rocks, or by compressing the litter enough to exert lateral forces through to the soil. For small, light-bodied snakes, on the other hand, lateral undulation or concertina locomotion would be effective on this loose surface only at the slowest speeds; faster lateral undulation would tend to scatter

the substrate horizontally, without meeting sufficient resistance to accelerate the snake. This could be noisy and conspicuous to predators as well as inefficient, and therefore other modes of locomotion would tend to be favoured by natural selection. Lateral undulation below the surface - 'swimming' through the litter or at the litter-soil interface - is an alternative practiced by many snakes and limb-reduced lizards (and may be strongly associated with the fossorial resting behaviour mentioned above). However, efficient subsurface locomotion requires specialisations of body form, head width, texture of body scales (Table 1) and other morphological traits (Savitzky, 1983). Sidewinding over the surface is another alternative, which apparently imposes less severe constraints on morphology (to judge by the difference in body proportions between *D. devisii* and *C. nigrostriatus*, for example). Sidewinding might often be the most effective option on leaf-litter as well as other shifting or smooth surfaces, particularly when rapid locomotion is required to minimise vulnerability or facilitate escape from predators.

Further possible advantages of sidewinding relate to the visual system. A reptile is best able to visually detect and localise features of its surroundings (prey, predators, refugia etc.) while its head is stationary (e.g. Magnusson, 1996), and the field of view is greatly increased by elevating the head above the substrate (e.g. Scanlon, 1998). Vision is therefore compromised during continuous lateral undulation, and of course it is practically useless below the surface. In sidewinding, the head is alternately stationary (or nearly so; Jayne, 1986) and elevated, so that this mode of locomotion may be advantageous when sight is important for orientation or escape manoeuvres. The slower pace and raised head posture of sidewinding *D. devisii* are consistent with this interpretation, since this species has much larger eyes than *Cryptophis, Parasuta* and most *Suta* spp., and is presumably more reliant on sight. Similarly, Klauber (1956) notes that during sidewinding by *Crotalus cerastes* 'the head can be kept

well elevated, either for defensive or observational purposes'. Apart from the snake's own visual system, that of a potential predator should also be considered: the body of a sidewinding snake presents a combination of near-stationary and rapidly moving parts, which might (especially in low-light conditions) produce sensory confusion similar to the flicker-fusion effect described for banded snakes (e.g. Greene, 1988).

In suggesting or testing possible selective advantages of locomotory behaviour, it is important to bear in mind that present-day habitats may have been extensively modified by human practices (burning, elimination of native herbivores, clearing, cattle grazing etc.), so the conditions in which species now occur may differ profoundly from those in which their behaviour evolved up until tens of thousands of years, or until hundreds or only tens of years ago. To some extent, species can be expected to have 'tracked' suitable habitat as such changes occurred, but particular features of organisms will not necessarily remain associated with the features of the habitat involved in their origins.

### Phylogenetic patterns

The restriction of reported sidewinding to a small number of snake species worldwide indicates that there have been relatively few evolutionary origins of the behaviour, and it may therefore be phylogenetically informative. If a 'tendency' to evolve sidewinding can be considered to characterise higher taxa, the most inclusive clade of potential sidewinders is that including all colubroids, tropidophiids and booids. Such a clade would also include acrochordids and bolyeriids, which are more closely related to colubroids than are tropidophiids (e.g. Cundall et al., 1993, Scanlon and Lee, 2000). However, it may be more parsimonious to assume separate origins in a number of lineages, rather than one origin and a much greater number of losses. This argument can be applied to the Australian elapid radiation. Except for *Laticauda*, each of the sidewinding species belongs to one large lineage within the Australian radiation,

the livebearing elapids with single subcaudals (Shine 1985). However, most of the livebearers tested do not sidewind, and the sidewinding species do not form a single natural group; this behaviour appears to be absent in some of the closest relatives of each.

The species of *Cryptophis*, *Suta* and *Parasuta* do represent a single distinct lineage, also including *Rhinoplocephalus bicolor* (Squarenosed Snake) which is probably the sister group to the other three genera (McDowell, 1967; Mengden, 1985; Hutchinson, 1990). However, the apparent absence of sidewinding in two species of *Cryptophis* makes it uncertain whether the behaviour is characteristic of the whole group, and I have not tested *R. bicolor*, or most species of *Suta* or *Parasuta*.

The nearest relatives of *Denisonia* apparently include *Drysdalia*, *Austrelaps* and *Notechis* (Mengden, 1985; chromosome groups 4 and 5). These snakes are largely diurnal, occupy mainly more mesic habitats, and none of them are known to use sidewinding (Table 1). Thus, sidewinding ability probably evolved within *Denisonia*, but the locomotion of *D. maculata* has not been studied.

### CONCLUSIONS

These observations show that some species of Australian elapids are able to use sidewinding locomotion, and that features of the habitat, evolutionary relationships, and other aspects of behaviour and morphology may all help to explain its pattern of occurrence. A few generalisations apply to most, if not all sidewinding species, whether boids, viperids, homalopsines, natricines, amphibious or terrestrial elapids. They are relatively small members of their lineages, terrestrial (as opposed to arboreal) but not highly fossorial, tend to be stocky rather than elongate in body form, and their habitats include open spaces with smooth, bare ground and/or shifting substrates separating refugia and foraging sites. The dichotomy of explanations based on 'shifting substrates' versus 'open terrain' (Cowles, 1956) appears to be false, in that

both conditions are found together in the habitats of most sidewinding species. A relatively elongate body form and 'sand-swimming' ability can be seen as distinct alternatives to sidewinding as adaptations for traversing open areas with loose substrates (Cowles, 1956, and see above), but they are not exclusive either, because *Cryptophis nigrostriatus* exhibits all three: it is an elongate, sand-swimming sidewinder.

More specifically, all of the Australian terrestrial elapid species in which sidewinding is reported are nocturnal, and occur in semi-arid woodlands where dry leaf litter forms a significant proportion of the ground cover (though they also extend to other habitats). I suggest that in these snakes, sidewinding is principally an adaptation for escape from predators, allowing rapid, quiet, and potentially visually confusing locomotion across open spaces on either firm or shifting substrates, including loose litter.

Further observations are required, not only to establish which other Australian species are capable of sidewinding (e.g. congeners and other close relatives of the species tested here), but to find out whether, and in what circumstances, they do so in natural conditions. While field studies and opportunistic observations are valuable, the behaviour of small, and especially nocturnal, snakes is very difficult to study in the wild. Unfortunately leaf-litter, unlike sand, is an unsuitable medium for even short-term retention of small animal tracks. Hypotheses concerning the occurrence and role of sidewinding and other specialised behaviours in elapids (e.g. slicing open lizard eggs, Scanlon and Shine, 1988; constriction, Shine and Schwaner, 1985; tail-waving as an apparent threat to prey, Scanlon, 1998) can be generated and tested more efficiently by detailed observation of captive snakes in 'naturalistic' enclosures, moving on a range of surfaces at different speeds, and offered diverse natural prey.

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**Table 1.** Terrestrial Australian elapid species tested for locomotory behaviour; N = number of individuals tested by author on short carpet and/or smooth wooden surface; SW = sidewinding present (+) or absent (-); fossor = 'fossorial' resting behaviour present (+), or usually rest under loose items of cover above soil (-);  scales = dorsal scales highly glossed (+), semi-glossy (±) or matt (-) in texture. *Acanthophis* and *Suta suta* based on Ehmann (pers. comm.).  *Cacophis* to *Vermicella* belong to oviparous lineages; *Acanthophis* to *Suta* represent the viviparous lineage (Shine, 1985).

| Genus | species | N | SW | fossor | scales |
|---|---|---|---|---|---|
| Cacophis | krefftii | 1 | - | - | ± |
| | squamulosus | 2 | - | - | ± |
| Demansia | psammophis | >6 | - | - | - |
| | sp. cf. olivacea | 1 | - | - | - |
| Furina | diadema | 2 | - | + | + |
| | ornata | 2 | - | + | + |
| Pseudechis | porphyriacus | >6 | - | - | ± |
| Pseudonaja | textilis | 2 | - | - | - |
| Simoselaps | australis | 2 | - | + | + |
| Vermicella | annulata | 1 | - | + | + |
| Acanthophis | antarcticus | - | + | - | - |
| Austrelaps | ramsayi | 4 | - | - | - |
| Cryptophis | boschmai | 5 | - | - | ± |
| | nigrescens | 6 | - | - | ± |
| | nigrostriatus | 2 | + | + | + |
| Denisonia | devisii | 1 | + | - | ± |
| Drysdalia | coronoides | 3 | - | - | - |
| | rhodogaster | >6 | - | - | - |
| Elapognathus | coronatus | 1 | - | - | - |
| Hemiaspis | damelii | 2 | - | - | - |
| | signata | >6 | - | - | - |
| Notechis | scutatus | 1 | - | - | - |
| Parasuta | dwyeri | 3 | + | + | + |
| Suta | punctata | 2 | + | + | + |
| | suta | - | + | | + |

# ASPECTS OF THE MORPHOLOGY AND ECOLOGY OF THE DEATH ADDER *ACANTHOPHIS ANTARCTICUS* (SERPENTES: ELAPIDAE) FROM MAGNETIC ISLAND, NORTH QUEENSLAND: DOES PREY SIZE DETERMINE DEGREE OF SEXUAL DIMORPHISM?

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## ABSTRACT.

Basic ecological and morphological data were collected from an insular population of death adders in tropical Australia. Two species of *Acanthophis* are generally recognised in the literature as occurring in eastern Australia: *A. antarcticus* and *A. praelongus*. Scale count data support the conservative view that only one taxon (*A. antarcticus*) is involved. The population was found to consist of two basic colour morphs (red and grey) and due to a tropical climate, selection for crypsis, rather than thermoregulation, may maintain the persistence of both phenotypes. Ecological data revealed smaller size at maturation, lower mean adult body size and possibly lower female reproductive frequency than any populations studied to date. In particular, no sexual dimorphism was found, contradicting a previous study (Shine, 1980) that female *A. antarcticus* attain much larger body sizes than males. Small mammals are rare or absent from the island and snake diets consisted of 100% scincid lizards. This may explain observed body sizes, reproductive frequency, and lack of sexual dimorphism.

## INTRODUCTION.

Death adders are venomous, highly cryptic ambush predators, using caudal tail luring to secure prey and show considerable convergence with the Viperidae (Shine, 1980). The genus occurs over large areas of mainland Australia in a diverse range of climatic regimes and habitats (Cogger, 2000).

Three species are generally recognised in the literature (common death adder *Acanthophis antarcticus*, northern death adder *A. praelongus* and desert death adder *A. pyrrhus*) but taxonomic distinctions between the three forms are sufficiently unstable that several authors only recognise *A. antarcticus* (Shine, 1980; Johnston, 1996). For *Acanthophis* in eastern and northern Australia there appears to be no way of clearly differentiating *A. praelongus* from *A. antarcticus* (Longmore, 1989; Cogger, 2000) and it is doubtful whether 'praelongus' can presently be regarded as a true species. Ramsay (1877) described 'praelongus' from a single specimen from Cape York and stated that a large number of specimens he encountered in north Queensland all conformed to *A. antarcticus*. In addition, 'praelongus' and *antarcticus* readily breed in captivity and produce fertile offspring (Aland, pers. comm.).

Such characters as increasingly gracile body form, degree of keeling on anterior and posterior dorsal scales and degree of projection of supraocular scales on a longitudinal gradient, from south to north, may represent clinal variation in a single widespread taxon. Until comprehensive taxonomic and/or genetic studies are undertaken, I believe all north Queensland *Acanthophis* should be referred to as *antarcticus*.

*Acanthophis antarcticus* is widespread in north east Queensland (Longmore, 1989; Ingram & Raven, 1994) and is known to occur on a number of continental islands (Covacevich, pers. comm.) including Magnetic Island (Low, 1978).

## MATERIALS AND METHODS.

### The study site

Magnetic Island (latitude 19°10' S, longitude 146°50' E) lies off the north Queensland coast 8km, across Cleveland Bay from Townsville. It is a high continental island with elevations of up to 540m and an area of some 5184ha. The island is dominated by large hills and spurs covered with extensive granite outcropping. Lowland alluvial flats produced by hillside erosion fringe the elevated portions of the island (Low, 1978).

Vegetation consists mainly of dry eucalypt woodland with some emergent hoop pine *Araucaria cunninghamii* on rocky slopes. Mangrove swamp fringes the western coastline and a few small patches of closed vine thickets occur in sheltered gullies and creek lines. Tree cover becomes increasingly sparse from the alluvial flats to steep rocky hillsides. The climate is tropical with distinct wet and dry seasons. Average annual rainfall is 1170mm, most of which falls in the wet season between December and March (Low, 1978).

A permanent human population of approximately 2000 people is situated in the lowland bay areas on the southern side of the island. The majority of the island is relatively undisturbed and almost half its area is National Park.

### Collection of data.

Between February 1997 and March 1999 the author resided on Magnetic Island and collected data from specimens of *A. antarcticus* whenever the opportunity arose. Most specimens were encountered on roads nocturnally or discovered diurnally in sheltered situations in suburban gardens.

Road killed specimens were collected, weighed, SVL (snout to vent length) and tail lengths (two specimens were omitted due to tail loss) measured to the nearest millimetre and dissected to determine food habits and reproductive condition. The reproductive condition of males was not investigated as Shine (1980) found that adult sized males appeared to be reproductive (i.e., had large testes, or sperm in efferent ducts) year round and so would reveal little about timing of reproduction.

Measurements of living snakes were obtained by inducing the snake to relax, momentarily, by tiring it. The front and hind ends are held in the operators hands and gently pulled in opposite directions until the snake is stretched to full length along a tape measure. This procedure is outlined by Fitch (1987). After measurement snakes were palpated for ingested prey and faecal material and if female, palpated for ova. Snakes, both living and dead, were sexed by manually applying pressure to the tail base and everting the hemipenes of males. After data collection snakes were released at their point of capture.

Ingested prey and faecal material was identified as closely as possible to species. Intact, recently ingested prey was weighed and measured.

Scale counts were made for 12 road killed specimens. Ventral and subcaudal scales were counted using the Dowling method (McDowell, 1967).

Two distinct colour morphs (red and grey) were readily discernable and snakes were placed into one or other of these categories.

Parametric statistical tests ( $t$ test) were performed on SVL, tail length and mass data.

### RESULTS

**Scale counts.** Scale counts were consistent with those of Cogger (2000) for *A. antarcticus* (mid-bodies 21, ventrals 110 -135, subcaudals 35 - 60). Scale count data are presented in Table 1.

**Colour morphs.** Of the 21 snakes examined, 13 (62%) were classed as red (8 males, 5 females) and 8 (38%) classed as grey (3 males, 5 females). Typical red and grey specimens are illustrated on the back cover.

**Body size.** Table 2 presents a summary of

SVL, tail length and mass of *A. antarcticus* in this sample. No significant difference in SVL or mass (P> 0.05) was found between males and females. Tail lengths were significantly different (P= 0.021) with males having longer tails.

**Food habits.** Of the 21 *A. antarcticus* examined, 10 (47.6%) contained food items in the stomach or readily identifiable remains (skink scales) in faeces. Specimens with recently ingested prey in the stomach (4) had a single prey item, with the exception of one that held three. Scincid lizards comprised 100% of the diet. Table 3 presents species and size of prey taken. Two 11x 7mm lizard eggs found in the stomach of one specimen (Table 3) are classed as the remains of a gravid skink and not an example of oophagy.

**Reproduction.** Only one reproductive female was found in the sample. This specimen was collected as a road kill on October 14, 1998 and contained a single 20 x 11mm ovum. The other nine females in the sample (6 dissected, 3 palpated) displayed ovarian follicles < 5mm or did not palpate for ova.

## DISCUSSION

**Scale counts.** Scale count data were unremarkable and fall within the known range for *A. antarcticus* and further support the authors views expressed in the introduction to this work.

**Colour morphs.** The work of Johnston (1996) demonstrated that *A. antarcticus* occurs in two distinct colour morphs (red, grey) controlled by two allelic genes at a single autosomal locus. The allele controlling the red morph is dominant to the allele controlling the grey. The frequencies of the two morphs was found to vary significantly between different regions of Australia with red snakes predominating in the north and east and grey snakes predominating in cooler southern areas (Johnston, 1996).

Such results indicate climatic factors may exert a selective influence by allowing the darker, grey snakes to more effectively ther-

moregulate in cooler southern portions of their range. Red specimens slightly out numbered grey in the Magnetic Island sample. The tropical climate of Magnetic Island coupled with increased thermoregulatory requirements of gravid females taking place in the warmest part of the year (wet season), would suggest that crypsis may be a more important selective factor in maintaining the two distinctive morphs on the island.

**Body size.** Body size and mass results in this study contradict the findings of Shine (1980) who found clear sexual dimorphism with females being much larger than males throughout the range of *A. antarcticus*. In addition, mean adult body size of Magnetic Island *A. antarcticus* (Table 1) is lower than the large sample examined by Shine (1980) where females were 580mm and males 440mm. All the specimens examined in this study were presumed to be adults based on the body size (388mm) of the single reproductive female collected and from extensive data which indicates that Australian elapids attain sexual maturity at around 75% of mean adult body size (Shine, 1991). In addition, Illidge (pers. comm.) removed a large number of *A. antarcticus* from residential properties on Magnetic Island during his duties as Park Ranger. He reported specimens typically ranging from 400 to 500mm in total length and measured only one exceptional specimen (sex unknown) of 885mm total length.

Longer tail lengths in male *A. antarcticus* are well known and with experience these snakes can be accurately sexed by visual inspection of tails. Shine et al (1999) suggest that sex divergence in tail length relative to body length in snakes reflects the action of sexual selection for male mating success.

**Food habits.** The 100% scincid lizard diet of Magnetic Island *A. antarcticus* is in contrast to mainland populations where mammals comprise as much as 32% of ingested prey (Shine, 1980). The situation on the island appears easily explained by an almost complete absence of mammals under 500g. The ter-

restrial mammal fauna of Magnetic Island is poor with only four native species (brush tail possum *Trichosurus vulpecula*, allied rock wallaby *Petrogale assimilis*, echidna *Tachyglossus aculeatus* and water rat *Hydromys chrysogaster*) and three introduced (koala *Phascolarctos cinereus*, feral cat *Felis domesticus* and black rat *Rattus rattus*) known to be extant on the island (Heinsohn, 1973, pers. comm.). The smallest of these (*R. rattus*) appears to be restricted to urban areas and is present in low densities (Heinsohn, pers. comm.; pers. obs.). Kutt (pers. comm.) recently trapped for mammals extensively at West Point and failed to capture any mammals smaller than *H. chrysogaster*.

The only readily available and abundant prey is a rich lizard fauna of some 25 species (Low, 1978, Fearn, 1998, Mott, pers. comm.) of which 17 are skinks. Of the skinks only four would be expected to attain or exceed 10g in mass (*Ctenotus robustus*, *C. eutaenius*, *Eulamprus tenuis* and *Tiliqua scincoides*), with *T. scincoides* present in very low densities and only ingestable by *A. antarcticus* as neonates or small juveniles (pers. obs.) A diet composed mainly of lizards may explain the smaller mean body sizes, smaller size at maturity and lack of clear sexual dimorphism in Magnetic Island *A. antarcticus*. A similar pattern was observed for insular populations of another Australian elapid (tiger snakes *Notechis scutatus*) where differences in maximum body size, degree of sexual dimorphism and frequency of individuals in size classes were best explained by adaptive responses to the availability of food resources on the respective islands (Barnett & Schwaner, 1985; Schwaner, 1985; Schwaner & Sarre, 1988). On one island, lizards were the only available source of prey, producing a 'dwarfed' population in which adult males and females were equally distributed in adult size classes (Schwaner, 1985). *Notechis scutatus* is relatively unselective in respect to prey type or size but adults rarely prey on skinks when other prey types are available (Schwaner, 1985; Shine, 1977; Fearn, 1993, 1995).

In a study that parallels the apparent situation for Magnetic Island *A. antarcticus*, Madsen & Shine (1993) compared a mainland and insular population of European grass snakes *Natrix natrix* (Colubridae). Female *N. natrix* from mainland populations were much larger than conspecific males. Sexual dimorphism was absent for an island population due to the direct influences of prey availability without any genetic modification of the population. The differences between the two populations of *N. natrix* were attributed to phenotypic plasticity rather than microevolutionary changes, based on the results of raising juvenile snakes from both populations until they had approached asymptotic body size.

**Reproduction.** Adult female *A. antarcticus* from across the taxon's range in mainland Australia ovulate in late spring or early summer with oviducal embryos occurring from December to late March. In addition, only half the females in any given year are reproductive (Shine, 1980). Magnetic Island *A. antarcticus* appear to follow similar trends but may reproduce even less frequently, as all females were collected in the wet season (October to March) when reproductives are ovulating or gravid. The apparently low levels of reproduction in this population (further evidenced by a complete absence of juveniles being discovered) may also be related to a diet of small ectotherms. Diurnal, surface active skinks are conspicuous and abundant throughout the island (pers. obs.) and with nearly half the snakes in this sample containing recently ingested skinks, they are apparently not difficult for the snakes to catch. However, snakes may be energetically disadvantaged on a diet of small skinks resulting in lower reproductive frequency for females. Such a situation may result in females maximising reproductive output by trading off increased size relative to males. Without a small mammal fauna there would appear to be no selective advantage for larger female body size.

Further studies of island populations of *A. antarcticus* are required particularly on islands with varying faunal assemblages to

test the relationship between size at maturity, mean body size, reproductive output and degree of sexual dimorphism in relation to prey types and abundance. Rearing of neonates under laboratory conditions will be important for determining if microevolutionary change or phenotypic plasticity are responsible for observed differences between mainland and island populations (Barnett & Schwaner, 1985; Madsen & Shine, 1993).

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**TABLE 1. Scale counts for Magnetic Island *Acanthophis antarcticus*. Numbers in brackets represent number of snakes displaying a particular count.**

| | Range | Individual counts |
|---|---|---|
| **Mid-bodies** | | |
| Males | 21 | 21(7) |
| Females | 21 | 21(5) |
| | | |
| **Ventrals** | | |
| Males | 118-126 | 118(1), 119(2), 121(1), 122(1), 123(1), 126(1) |
| Females | 118-126 | 118(1), 122(3),126(1) |
| | | |
| **Subcaudals** | | |
| Males | 44-56 | 44(1), 49(1), 53(2), 55(2), 56(1) |
| Females | 49-53 | 49(1), 50(1), 51(1), 53(1) |

**TABLE 2. Summary of Magnetic Island *Acanthophis antarcticus* body length SVL(mm), mass (g) and tail length (mm).**

| | Mean | S. D. | Range |
|---|---|---|---|
| **Males (n= 11)** | | | |
| SVL | 399.18 | 35.869 | 333-450 |
| Weight | 63.545 | 21.961 | 38-104 |
| Tail length | 90.800 | 9.0406 | 80-104 |
| | | | |
| **Females (n= 10)** | | | |
| SVL | 422.30 | 46.181 | 370-510 |
| Weight | 77.100 | 18.150 | 50-102 |
| Tail length | 80.333 | 8.8882 | 71-95 |

**TABLE 3. Prey records for Magnetic Island *Acanthophis antarcticus*.**

| Species | No. of records | Total length (mm) | Mass (g) |
|---|---|---|---|
| *Ctenotus robustus* | 2 | 100 | 6 |
|  |  | 150 | 18 |
| *Carlia schmeltzii* | 3 | 110 | 6 |
|  |  | 150 | 8 |
|  |  | 110 | 5 |
| *C. rhomboidalis* | 1 | 105 | 4.5 |
| Unidentified skink remains | 6 |  |  |
| Skink eggs | 1 | 11 x 7 |  |

# THE HOUSE GECKO *HEMIDACTYLUS FRENATUS* AND FLOWERPOT BLIND SNAKE *RAMPHOTYPHLOPS BRAMINUS* IN WESTERN AUSTRALIA

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The genus *Hemidactylus* is widespread throughout the worlds tropical and temperate regions (Cogger, 1992). *H. frenatus* has been, and probably continues to be, introduced to Australia, probably in cargo from south-east Asia where it naturally occurs. It is now well established in some settled areas in northern Australia. On current literature its distribution outside Western Australia is from Darwin south to about Renner Springs, Northern Territory (Fyfe, 1981) and towns of northern Queensland south to Brisbane (Wilson and Czechura, 1995), including islands in the Torres Strait (Covacevich and Couper, 1991). This gecko appears to be entirely dependent on human settlements for its dispersal in Australia, having disappeared from settlements that are abandoned (Ehmann, 1992). Currently there is no evidence to suggest that it can adapt to and colonise undisturbed habitats, although in some areas it is known to have displaced other human-associated gecko species e.g. *Gehyra australis* and *Oedura rhombifer* in Australia (Greer, 1989).

Storr *et al.* (1990) state that *H. frenatus* in Western Australia occasionally arrives on ships and airplanes at Fremantle and Guildford in Perth, but is only established on West Island (Ashmore Reef) and perhaps on the Montebello Islands, although it was not reported from the Montebellos by Burbidge *et al.* (2000) and Storr *et al.* give no further information to justify their statement. The Western Australian Museum has specimens R58823-25 from West Island. Apart from this, and to my knowledge, no further records of *H. frenatus* have been confirmed from mainland Western Australia. Considering its ability to be transported in freight and vehicles plus the long term settlements in the Kimberley, it is surprising that it appears relatively unestablished in this region, or maybe it has been simply overlooked due to its introduced status and superficial resemblance to *Gehyra* spp. Without closer examination in the hand of the key diagnostic features distinguishing these two genera they can be incorrectly identified (Cook, 1990). However the distinctive loud "chk-chk-chk" call emitted by *H. frenatus* could hardly go unnoticed by residents in an established population.

To draw attention to the presence of this species in Western Australia and hopefully stimulate additional observations I present the following records, which may indicate the beginning of establishment by this species in the Kimberley region, although this could also be considered premature. Their establishment in this sparsely populated region could be similar to that observed by Wilson and Czechura (1995) for Brisbane where they "appear to have become established ......within the past decade". Not surprisingly, *H. frenatus* has been recently collected at Kununurra 15°46'S 128°44'E (R131179, R131880, R137417, R140788) and Broome 17°58'S 122°14'E (R132501, R132949-52) on hotel buildings. They have also been observed by Brian Bush on the patio roof at the Argyle Diamond Village 16°40'S 128°22'E on 17 February 1999. The latter may be an established population owing to the amount of calling made through the night (B. Bush pers. comm.). These localities represent the western and eastern extremities of the Kimberley region. On 15 February 1999 John Smith and I collected an adult (R135635) on the toilet wall at Sandfire Roadhouse in the Great Sandy Desert 19°46'S 121°05'E. This probably represents a "one off" introduction similar to that described by Lloyd (2000) as no other individuals were seen.

Closer attention should be made by resident

and visiting naturalists to settled areas in northern Western Australia of arboreal geckos to determine the establishment and ongoing dispersal of this species. These observations of *H. frenatus* in Western Australia follow the first confirmation of the introduced typhlopid *Ramphotyphlops braminus* in this state (Coate, 1997). Further Western Australian records for the latter species include Broome 17°58'S 122°14'E(R145239), Port Hedland 20°19'S 118°36'E (R132061) and Karratha 20°44'S 116°51'E (R132598-99, R145082) in the Kimberley and Pilbara regions.

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# PREVALENCE OF THE PLEROCERCOID OF *SPIROMETRA ERINACEI* (CESTODA) IN THREE SPECIES OF ELAPID SNAKES IN THE MELBOURNE REGION

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## INTRODUCTION

Available information on the cestode *Spirometra erinacei* in anurophagous snakes is largely anecdotal or descriptive (Young, 1939; McCracken, 1988; Cermak, 1991; Fitzgerald, 1994; Watharow, 1997). *S. erinacei* is believed to have been introduced to Australia via foxes and domestic cats with early European settlers (Purvis, 1989). Now the cestode appears to be widespread in most parts of Australia, in mammals, reptiles and amphibians (Young, 1939; Spratt *et al.*, 1990; Barton, 1994; Callahan, 1996).

The *Spirometra* life cycle begins when the coracidium hatches from eggs laid via faeces in water. It swims freely until ingested by invertebrates (e.g., water fleas), where it develops into a procercoid (first stage larva). Infection in tadpoles or frogs is by ingestion of small aquatic invertebrates. Anuran prey is ingested by paratenic hosts, lizards and snakes, in which the plerocercoid develops. The cycle is completed when a mammalian carnivore ingests an intermediate or paratenic host, with the adult worm inhabiting the carnivore's intestines (Bennett, 1968; Sastrawan, 1978; McCracken, 1988; Purvis, 1989; Cermak, 1991).

Commonly referred to as "skin worms", plerocercoids are commonly seen in captive snakes, particularly anurophagous species such as Red-bellied Black Snakes *Pseudechis porphyriacus* and Green Tree Snakes *Dendrelaphis punctulatus*, usually in either wild-caught specimens or when wild prey has been fed (McCracken, 1988). Infestation rarely causes disease in captivity, but large burdens can result in loss of appetite and weight loss (McCracken, 1988). Large burdens have also been suggested to be immunosuppressive, causing sluggishness and facilitating secondary infections (Purvis, 1989).

A single instance of snake mortality has been attributed to infestation: an adult *Pseudechis porphyriacus* showed bleeding from the vent and violent spasms followed by death (Purvis, 1989). Experimentally, infested *Litoria caerulea* tadpoles had stunted growth and swimming difficulties (swimming upside down), with only one tadpole of 60 surviving to metamorphosis (Sastrawan, 1978).

This paper presents data on the prevalence of *S. erinacei* plerocercoids in three elapid species, the Eastern Tiger Snake *Notechis scutatus*, Lowland Copperhead *Austrelaps superbus* and Eastern Brown Snake *Pseudonaja textilis*, in the Melbourne area.

## METHODS

Snakes were captured by licensed wildlife controllers from residential properties in the Melbourne metropolitan area (see also Watharow, 1997). Collections were made from October 1996 to April 1997. Some additional snakes were obtained freshly dead, killed by home owners, domestic pets or land clearing activities.

Snakes were measured, sexed and weighed, and dissected for helminth burdens. Snakes and parasites were then preserved in 10% formalin. Burdens were categorized as mild (<5 separate plerocercoids), moderate (5-10) or heavy (>10).

## Table 1. Data from *Notechis scutatus*

| Snake # | SVL (mm) | TL (mm) | Mass (g) | Sex | Remarks |
|---|---|---|---|---|---|
| 1 | 920 | 170 | 387 | F | heavy |
| 2 | 600 | 115 | 123 | F | mild |
| 3 | 740 | 120 | 231 | F | mild |
| 4 | 620 | 110 | 88 | F | mild |
| 5 | 720 | 150 | 196 | F | mild |
| **Mean** | **720** | **133** | **205** | | **35.7% of females infested** |
| 6 | 900 | 160 | 360 | F | not infested |
| 7 | 730 | 135 | 300 | F | not infested |
| 8 | 365 | 70 | 22 | F | not infested |
| 9 | 640 | 120 | | F | not infested |
| 10 | 790 | 140 | 250 | F | not infested |
| 11 | 530 | 100 | 66 | F | not infested |
| 12 | 520 | 90 | 62 | F | not infested |
| 13 | 760 | 130 | 203 | F | not infested |
| 14 | 660 | 120 | 136 | F | not infested |
| **Mean** | **655** | **118.3** | **174.8** | | **64.2% of females not infested** |
| 15 | 665 | 120 | 152 | M | heavy (30+) |
| 16 | 790 | 90* | 281 | M | mild |
| 17 | 1080 | 70* | 862 | M | mild |
| 18 | 870 | 165 | 310 | M | mild |
| 19 | 810 | 150 | 337 | M | mild |
| **Mean** | **843** | **119** | **332.6** | | **35.7% of males infested** |
| 20 | 820 | 160 | | M | not infested |
| 21 | 770 | 150 | 280 | M | not infested |
| 22 | 950 | 40* | 690 | M | not infested |
| 23 | 630 | 130 | 161 | M | not infested |
| 24 | 800 | 140 | 299 | M | not infested |
| 25 | 730 | 140 | 267 | M | not infested |
| 26 | 790 | 120 | | M | not infested |
| 27 | 740 | 120 | 177 | M | not infested |
| 28 | 790 | 145 | 228 | M | not infested |
| **Mean** | **877.5** | **128.1** | **300.2** | | **64.2% of males not infested** |
| **Total mean** | **740** | **123.9** | **247.5** | | **35.7% of snakes infested** |
| **Range** | **365-1080** | **40-170** | **22-862** | | |

## Table 2. Data from *Austrelaps superbus*

| Snake # | SVL (mm) | TL (mm) | Mass (g) | Sex | Remarks |
|---|---|---|---|---|---|
| 1 | 790 | 105* | 290 | F | moderate<br>**10% of females infested** |
| 2 | 730 | 145 | 250 | F | not infested |
| 3 | 630 | 130 | 160 | F | not infested |
| 4 | 540 | 120 | 110 | F | not infested |
| 5 | 350 | 70 | | F | not infested |
| 6 | 460 | 95 | 52 | F | not infested |
| 7 | 470 | 100 | 47 | F | not infested |
| 8 | 560 | 130 | 129 | F | not infested |
| 9 | 740 | 145 | 166 | F | not infested |
| 10 | 920 | 135 | 391 | F | not infested |
| **Mean** | **600** | **118.8** | **163.1** | **F** | **not infested** |
| 11 | 1100 | 170 | 520 | M | heavy (50+) |
| 12 | 980 | 190 | 831 | M | heavy (70+) |
| 13 | 950 | 152 | 543 | M | heavy (30+) |
| 14 | 840 | 140 | 362 | M | mild |
| 15 | 680 | 145 | 298 | M | mild |
| 16 | 730 | 150 | 188 | M | mild |
| 17 | 800 | 160 | 390 | M | mild |
| 18 | 860 | 170 | 525 | M | mild |
| **Mean** | **867.5** | **159.5** | **457.1** | | **61.5% of males infested** |
| 19 | 730 | 135* | 177 | M | not infested |
| 20 | 900 | 150 | 480 | M | not infested |
| 21 | 810 | 150 | 270 | M | not infested |
| 22 | 760 | 145 | 342 | M | not infested |
| 23 | 820 | 170 | 452 | M | not infested |
| **Mean** | **804** | **150** | **344.2** | | **38.4% of males not infested** |
| 24 | 490 | 110 | 150 | ? | not infested |
| 25 | 490 | 110 | | ? | not infested |
| **Total mean** | **725.2** | **136.8** | **309.6** | | **36% of snakes infested** |
| **Range** | **350-1100** | **70-195** | **47-871** | | |

## Table 3. Data from *Pseudonaja textilis*

| Snake # | SVL (mm) | TL (mm) | Mass (g) | Sex | Remarks |
|---|---|---|---|---|---|
| 1 | 1000 | 200 | 402 | F | mild |
| 2 | 770 | 150 | 169 | F | mild |
| **Mean** | **885** | **175** | **285.5** | | **40% of females infested** |
| 3 | 1000 | 200 | 290 | F | |
| 4 | 1000 | 200 | 380 | F | |
| 5 | 850 | 190 | 340 | F | |
| **Mean** | **950** | **196.6** | **336.6** | | **60% of females not infested** |
| 6 | 1220 | 150 | 608 | M | mild |
| | | | | | **33.3% of males infested** |
| 7 | 1080 | 200 | 582 | M | |
| 8 | 1300 | 200 | 816 | M | |
| **Mean** | **1027.5** | **200** | **448** | | **66.6% of males not infested** |
| **Total mean** | **1027.5** | **173.7** | **448.3** | | **37.5% of snakes infested** |

Legend: SVL = snout-vent length; TL = tail length; * = incomplete tail

## DISCUSSION

While the sample was small, especially for *P. textilis*, confined to a six month period and not confined to a single location, it does provide useful information on prevalence of infestation between sexes and sizes in the three species around the Melbourne metropolitan area.

The subcutaneous swellings caused by the plerocercoids consisted of between one and five individuals, and were visible as external lumps 5-20mm in diameter. Plerocercoids were common in the dorsal caudal regions of the snakes, and even in heavy infestations,were never seen further cranially than the heart. Heavy burdens were largely free floating in the body cavity or situated loosely on body organs.

Snakes that are largely or exclusively frog eaters often have large plerocercoid burdens (Sastrawan, 1978; Purvis, 1989), and hence heavy infestations with plerocercoids are commonly viewed as evidence of heavy anuran predation (Purvis, 1989; Cermak, 1991). However, this argument may be invalid, as snakes can also become infected by consuming other infected paratenic hosts. I have observed plerocercoids in the Eastern Water Skink *Eulamprus quoyii*, and it is possible that ophiophagous snakes such as *A. superbus* and *P. textilis* (Shine, 1987, 1989; Watharow, in press) may obtain their burdens from other snakes.

At least in *N. scutatus* and *A. superbus*, this study demonstrates that larger snakes are more likely to be infected, and carry larger burdens, than small snakes. The smallest observed infected snake was a *Notechis* with a length of 600mm and mass of 123 g (Table 1). This is likely to reflect the longer exposure of larger snakes to infected prey. However,

not all large snakes were infected.

There was no difference between sexes in the proportion of infected *Notechis* (Table 1). However, in *Austrelaps*, fewer females were infected than males (Table 2). This may be due to the larger number of juvenile and subadult females than males examined in this species.

While the sample size for *Pseudonaja textilis* is small, the low frequency of parasitism despite the large size of the snakes seen suggests that *S. erinacei* is unlikely to occur in large numbers in this species. This finding is in agreement with the data of Watharow (1998) from roadkills in north western Victoria, and unpublished data for 18 *Pseudonaja textilis* from the Adelaide and Barossa Valley regions (pers. obs.). The cestode larvae could either be absent from many *P. textilis* prey, or may not be common in *Pseudonaja* habitats.

The higher frequency of parasitism in *Notechis* and *Austrelaps* may reflect their prey preferences, as both are regular anuran predators in the wild (Shine, 1977, 1987), while *Pseudonaja* preys on lizards or frogs as juveniles, but mostly lizards and mammals (especially the mouse *Mus musculus*) as adults (Shine, 1989; Watharow, in press). The few snakes found with large plerocercoid burdens (one *Austrelaps*, four *Notechis*) were captured near dams, lakes and coastal swamps, all prime frog habitat.

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# A NOTE ON TWO PREDATION EVENTS OF THE GIANT BURROWING FROG, *HELEIOPORUS AUSTRALIACUS*.

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The giant burrowing frog (*Heleioporus australiacus*) is a large (up to 100 mm), burrowing myobatrachid frog found in south-eastern Australia. This species has three obvious defensive mechanisms against predators. Their skin is covered with glands that produce a white, sticky skin secretion that is presumably either toxic or unpalatable (Fig. 1; Daly, 1996). Individuals can also inflate their bodies and stand on "tippy-toes" to maximise their apparent body size (Fig. 1) presumably to either frighten predators or appear to be too large to consume. Thirdly, frogs of either sex can emit a loud and high-pitched scream that may serve to startle potential predators (F. Lemckert, pers. obs.). Such mechanisms would appear likely to offer significant protection from predators. However, we report two occasions when a giant burrowing frog has fallen victim to a vertebrate predator.

On the 13th December 1999, eight giant burrowing frogs implanted with two gram single-stage radio-transmitters (SIRTRACK, New Zealand) were released back into Yambulla State Forest (37°16'68" 149°36'17"), in far southeastern New South Wales (Fig. 2). This work was being performed as part of a radio-tracking study to determine the habitat use patterns and movements of this species (Lemckert, in prep). Each frog was relocated on a daily basis for the first three days after release, and then on a weekly basis.

On the night of the 14th of December 1999, one of these frogs, a female of just over 60 grams, was located and flagging tape used to mark its position. The following day the transmitter signal was relocated in a gully some 150 metres distant and, judging by the variable signal, the individual was moving. One of us (AT) drove down a nearby track towards the direction of the signal. On exiting the vehicle a large (1.5 metres) lace monitor (*Varanus varius*) was observed crossing the track and a check of the signal confirmed that it was emanating from the lace monitor. Back at the marked site a hole approximately 15 centimetres deep and 5cm diameter had been dug into hard packed sandy soil, presumably by the lace monitor as it unearthed the frog.

On the 17th April 2000 a daytime search was performed for another female giant burrowing frog, also just over 60 grams, that had been re-implanted with a transmitter. The signal lead to a gully that was approximately 600 metres south-west of the frog's last known location. At this point, a red-bellied black snake (*Pseudechis porphyriacus*) of just over one metre long was seen moving along the gully. The snake was followed along the creek line before it took cover in thick vegetation, the moving signal confirming that the transmitter was inside the snake.

Predators of the giant burrowing frog have not previously been recorded. However, it is not entirely surprising to record either predator as eating one of these frogs. The red-bellied black snake is well known for its anurophagous habits and is considered to be a frog specialist (Shine, 1977; Cogger, 2000). While the lace monitor is recorded as taking insects, reptiles, small mammals, birds and carrion (Vincent and Wilson, 1999; Cogger, 2000), it is a highly opportunistic predator and a large frog would appear to be a suitable meal. It is interesting to note however, that while tropical varanids often consume frogs (Shine, 1986) gut content analysis of *Varanus varius* specimens has so far not revealed amphibians in their diet (51

samples D. Carter, pers. comm.; 56 samples Weavers,1989).

The lace monitor was clearly able to detect the frog it consumed even though it was burrowed 15cm below the surface. It seems improbable it could have detected the frog's burrowing site visually as the frogs temporary burrows are essentially invisible. This is due to the soil that covers the entrance as the frog rotates while descending, and finding the exact location is made even more difficult beneath leaf litter and log cover (A. Towerton and F. Lemckert, pers. obs.). The most likely means of detection was by scent as all varanids have an excellent ability to detect scents (Vincent and Wilson, 1999). Whether the lace monitor can detect giant burrowing frogs on a regular basis or whether there were unusual circumstances in this instance is not known.

Giant burrowing frogs generally remain burrowed during the day (Lemckert, in prep.) and so should be relatively safe from a red-bellied black snake, which has generally diurnal habits (Cogger, 2000). However, this species of snake will occasionally hunt nocturnally (F. Lemckert, pers. obs.) if the night-time temperatures are warm enough. The temperature at 10:00pm the previous night was 14ºC. Presumably the temperature around dusk (about 6:00pm) would have been near 20ºC and so may very well have been high enough for the snake to have been active in the early evening. At this time, when the conditions are right (warm temperature and rainfall), the frogs can be seen at the entrance to the daytime burrow (A. Towerton, pers. obs.) and so a snake could encounter a newly emerged giant burrowing frog.

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Figure 1. A giant burrowing frog exhibiting a good display of two of its defence strategies: standing on 'tippy-toes' and exuding a sticky white secretion.



Figure 2. Location of Study Site
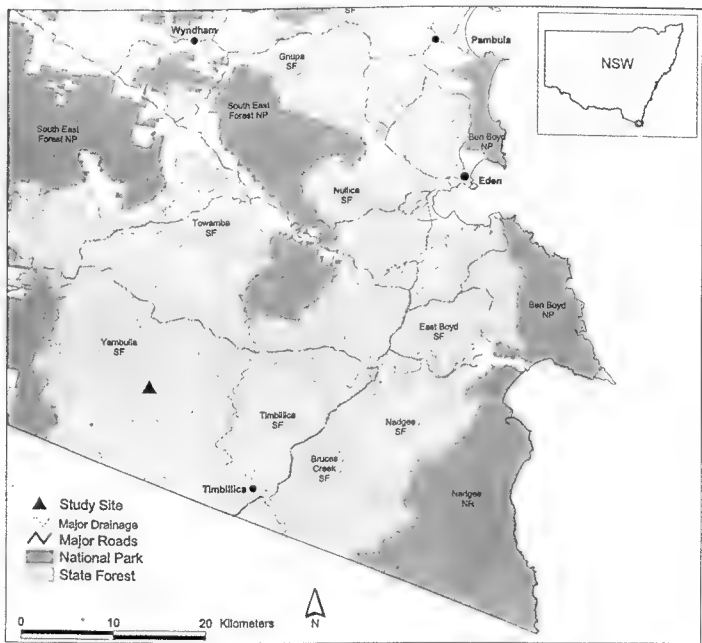
# AGGREGATIONS AND BASKING IN GRAVID FEMALE LITTLE WHIP SNAKES
## *SUTA FLAGELLUM* (ELAPIDAE).

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## ABSTRACT

Field observations of gravid female Little Whip Snakes (*Suta flagellum*) forming small, temporarily stable aggregations of between two and four individuals are described. The aggregations appear to form in December or January and persist up until parturition in mid to late February. During daylight hours gravid females in aggregations often bask semi-exposed from crevices or emerge fully to bask in grassy mats a short distance from their refuge. When either basking or concealed, females tended to maintain body contact. About one-half of all gravid females located in the field were part of an aggregation. The significance of aggregations in this species is discussed.

## INTRODUCTION

The Little Whip Snake (*Suta flagellum*) is a small nocturnal live-bearing elapid snake that occupies a variety of habitats from sclerophyll forest to coastal heath of south-eastern Australia (Rawlinson, 1965; Shine, 1988; Wilson & Knowles, 1988; Cogger, 1992; Ehmann, 1992). Details of the species' natural history, including diet, reproduction and behaviour are described in Fyfe and Booth (1984), Shine (1988) and Turner (1989, 1992, 1996). Of particular relevance to this work is the timing of reproductive events in *S. flagellum*. Mating has been recorded in the months October and November (Turner, 1992; Valentic, 1993), gravid females have been located in the field from December through to April and parturition typically occurs in February and March (Turner, 1989, 1996; but see Fyfe & Booth, 1984). Overwintering aggregations have been recorded in *S. flagellum* (James, 1979; Fyfe & Booth, 1984; Ehmann, 1992) and will be treated in detail elsewhere (Turner, in prep.).

The aggregations which form the subject of this work are associated with gravid female snakes. There is no widely accepted definition of the term "aggregation" in the literature as it pertains to snakes (see Graves & Duvall, 1995). For the purpose of this work the most convenient definition of an aggregation is the occurrence of two or more individuals, either beneath, or in association with, the same refuge. An important aspect of gravid female aggregations is that they generally occur during a period of the year when snakes are active, in contrast to overwintering aggregations whose cohesion would seem to be largely, if not entirely, the result of unsuitable conditions for activity.

There are few records of gravid female aggregations in the Australian elapids, and the elapid family generally (Shine, 1979; Shea et al., 1993; Graves & Duvall, 1995). In only a few Australian elapid species have aggregations of gravid females been monitored to determine whether they are persistent (i.e., occur for only part or the entire gestation period) or merely temporary associations (e.g., Sault, 1977; Shine, 1979) and none have been monitored through to parturition. Furthermore there have been no studies concerned with explaining the function of such aggregations.

This article reports the occurrence of small aggregations, diurnal emergence and basking in gravid female *S. flagellum* in the field. The question as to the function of the aggregations is beyond the scope of the present study; instead this work provides a qualitative description of the behaviour of gravid females in aggregations. This was achieved by the regular inspection of several aggregations in the field until their eventual break-up.

## METHODS

Aggregations were located serendipitously in remnant basalt plains grasslands to the north and west of Melbourne in the course of conducting a survey of *S. flagellum* populations in these areas. Upon locating an aggregation, its size, and the size, sex, reproductive status, and individual identifying markings of the snakes in the aggregation, were recorded. Determining the sex of adult *S. flagellum* merely requires a clear view of the tail (see Turner, 1992) and consequently it was usually not necessary to remove snakes from their refuge for this purpose. A female snake encountered during the months of November through to April was deemed to be gravid (i.e., as containing embryos) if the posterior half of the body was distended and taut; this has proved to be a very reliable indication of gravidity (pers.obs.). All females from the three aggregations described below were of this appearance. It was unnecessary to permanently mark individuals since variation in body colour, the distribution of black pigment on the head/snout, scale blemishes and anomalies were sufficient to identify particular individuals. It was necessary to use on some occasions a small torch and a prodding stick in order to determine the identity of individuals located down crevices. Attempts were made to minimise handling or unduly stressing the snakes in order to avoid risking the premature break-up of aggregations. For this reason handling occurred only once. Details recorded were snout-to-vent lengths (SVL), tail lengths (TL) in millimetres (mm) and mass (M) in grams (g). Each aggregation was typically inspected at one or two weekly intervals up until their eventual break-up. The aggregations were based around particular refuge sites and these sites were inspected on each visit for the presence of sloughed skin, urates and faecal material. Details of the site such as aspect, linear dimensions of the refuge, surrounding vegetation cover and proximity to nearest water as well as any other discerning features were noted. Weather conditions were also noted and the maximum day-time (shade) temperatures are given from data provided by the Bureau of Meteorology (Melbourne, Vic.). The time of day when aggregations were inspected is quoted in local time (Eastern Summer Time between the months November-March). A dual thermometer with a temperature probe was used to determine the temperatures at basking sites and in refuges and was accurate to 0.1ºC. The following abbreviations were used in describing weather and temperature: S= sunny, O= overcast, R= rain, BT= basking site temperature, RT= refuge temperature, AT= aperture (opening) of crevice temperature. On each subsequent visit refuges were carefully approached so as to minimise disturbance to females. On some occasions temperatures were not, or were only in part, taken to minimise disturbance. The positions and behaviour of snakes were noted. Snakes were deemed to be 'basking' if they were lying immobile either partly or completely exposed to the sun.

## OBSERVATIONS

The observations described below consist of the location and subsequent monitoring of three aggregations of gravid females from two localities on grasslands to the north and west of Melbourne. Two of the aggregations were discovered at Deer Park (37º46'S 144º46'E) when searching beneath rocks on the 21 December 1991 (aggregation 1) and the 25 January 1992 (aggregation 2). The third aggregation was located in rocky undulating grasslands in Bundoora (37º42'S 145º03'E) on the 11 January, 1992 (aggregation 3).

While the observations of just three aggregations are described below, a number of other examples of all (adult) female aggregations were observed in the course of field work during summer months and are briefly described. These aggregations were not however inspected on a regular basis and in some cases the snakes could not be extricated from their refuge and thus their reproductive status could not be ascertained. In several aggregations where gravid females were

temporarily removed from their refuge for processing some or all of the specimens on next inspection had moved from the refuge and could not be located. In all cases the aggregate size did not exceed four. For these reasons the scope of this article is restricted to the description of three particular aggregations which were regularly inspected.

## Aggregation 1.

This aggregation consisted initially of two, and later, three gravid females. They occupied an exfoliating basalt rock refuge consisting of two vertical and one horizontal crevice formed by a fractured block (0.47 x 0.22 x 0.20m) of basalt which neatly slotted into a larger basalt rock. The lowest part of the block was approximately 8cm above the substrate and the vertical crevices allowed snakes to lodge themselves up to 55cm above ground level while remaining concealed. This particular refuge was located on a well drained gentle slope in open rocky grassland subject to all day sun and located some 500m away from nearest water (Kororoit Creek). The only ground cover in the area was basalt rock and much of this (>90%) rested directly on the soil substrate; exfoliating rock was comparatively rare. The refuge had been occupied during the previous winter by two juvenile males. On the 2 November 1991 an adult male and female were observed at the base of the refuge. The gravid female aggregation was discovered on the 7 December 1991 when two gravid females were observed in amongst a grassy mat at the base of the rock where they appeared to be basking. One of these females was the specimen located previously on the 2 November. A third gravid female joined these two some time between the 4-11 January. All three females were conspicuously gravid. During the 2-4 January much of the grassland was subject to a controlled burn. As a consequence the vegetation surrounding the aggregation was burned to ground level leaving only the charred base of grass tussocks and much exposed soil. The area around the base of the rock where basking

took place was burned, though a charred layer of grass leaves remained at the base providing some cover, albeit much reduced. The gravid females appeared to be unaffected by this event to the extent that they remained at the site, continued to bask, and did not bear any signs of injury. The crevices within refuge would have afforded complete protection from the fire.

The measurements of the snakes were- male: SVL>340mm, TL=62mm; Female I : SVL=310mm, TL=42mm. Female III was retained on the 15th February- her measurements were: SVL=266mm, TL=39mm, M=21.17g. On the 29 February she produced a litter of four (two of which were severely deformed; see Turner (1998b) for details). Female II was not measured but had an estimated SVL of 300mm.

The details of each visit to the site are as follows:

2 November 1991, 1300hrs - An adult male and female *S. flagellum* were observed in a mat of Kangaroo Grass (*Themeda triandra*) at the base of the rock. They were well concealed by tussocks and were in close proximity to the refuge. The male was quite active and appeared unsettled while the female was by contrast inactive for the 15 minute period they were observed. The male's activity was confined to a small area around the female but tussocks obscured the nature of the activity. On handling both were warm and this was reflected in their rapid movements. The female was quite robust and was either gravid or contained enlarged ova. O (31°C), BT=27°C, RT=22°C.

9 November, 1045hrs - The same female was observed partly exposed and active within the rock crevice. No other specimens were visible. R (20°C), RT=18°C.

7 December, 1015hrs - Two gravid females were observed intertwined at the base of the refuge in the grassy mat in partial sun. One of the specimens was the female recorded on the 9 November (female I), while the other female (II) had not been previously recorded.

They were observed for a 15 minute period during which time they moved very little, only slightly altering their positions but remained in body contact. S (21ºC), BT=24.9ºC.

21 December, 1450hrs & 2050hrs- At 1450hrs the same two females were present: one adult female (I) was observed partly exposed beneath the grassy mat at the base of the rock while the previously observed female (II) was visible down the horizontal rock crevice. S (21ºC), BT=24.2, RT=18.5ºC. When revisited that evening at 2050hrs both females were lodged down the horizontal crevice in direct body contact and no significant movement was detected. S (21ºC), AT=15.2ºC.

11 January, 1045hrs - The two females (I & II) were observed basking intertwined in the grassy mat at the base of the rock. My approach evidently disturbed them and they immediately retreated, one after the other, into the vertical crevice. Both used the same escape route which was along the base of the rock (a distance of about a 0.4m), partly concealed by the charred ground layer, and then up through a groove into the crevice. The crevice was then examined to reveal the presence of a third gravid female (III) in the horizontal crevice. This female had not been previously recorded. S/O (22ºC), BT=26.3ºC.

18 January, 1130hrs & 1545hrs (approx.) - Two of the females (I, III) were observed basking semi-exposed from different crevices while female II was basking in the grassy mat at the base of the rock. The latter specimen, after 10 minutes of observation during which time it lay still, slowly made its way into the crevice; it seemed unaware of my presence. O (22ºC), BT=26.8ºC. At 1545hrs the same day all females had receded well into the crevices and were only just visible- it was not clear whether females were in direct body contact. S, AT=42.0ºC, RT=33.1ºC.

25 January, 1040hrs & 1405hrs - At 1040hrs all three females were observed near the opening of the top vertical crevice. Female I had a 7cm portion of her posterior body exposed from the crevice in direct sunlight,

while the remainder of its body was concealed. Each of the females was about 1cm apart. Females I and II were opaque in appearance suggesting that sloughing was imminent. O, AT=24ºC, RT=18ºC. At 1405hrs all three females remained in essentially the same positions. S (23ºC), AT=28.5ºC.

8 February, 1100hrs, 1425hrs & 2135hrs - At 1100hrs two of the females (II & III) were basking in direct body contact at the base of the rock while the other (female I) was at the edge of the vertical crevice. Feamles moved very little. S (28ºC), BT=28ºC. When revisited in the afternoon (at 1425hrs) all females had retreated into the crevice BT=34.2ºC. On later inspection that evening (at 1935hrs) all three females were lodged down crevices, two in direct body contact down the horizontal crevice, the third down a vertical crevice. RT=17ºC.

15 February, 1110hrs - The refuge site was inspected, but no females were visible either in the grassy mat or down crevices. The basalt block was removed to reveal just one gravid female (III). S (25ºC).

22 February, 1400hrs - Female I which was absent from the refuge on the previous visit was located beneath a rock some 30m away. It had a 'hollow' abdomen, typical of post-parturient females and a palpable mass in the mid-body region, indicating it had recently fed. The first neonate for the season was discovered about 50m away from the refuge on this visit.

Several urates and two faecal masses (containing skink scales) were located around the refuge site possibly indicating that there was limited feeding during the period December through to February. It was apparent that individuals basking in the grassy mat had a well defined escape route back into the refuge which they used whenever disturbed. There was an alternative shorter escape route available, though it required snakes to fully expose themselves and it was not ever observed being used. Females were not observed moving down to the basking site so

it is not known whether they used the same route for this purpose.

## Aggregation 2.

This aggregation consisted of two gravid females. This pair was discovered on the 25 January 1992 in flat, rocky and fairly degraded grassland that was subject to light grazing. The site was some 350m away from aggregation I but had not been burnt that season. The females were located when a relatively small rock (0.43 x 0.25 x 0.20m) with a convex base lying directly on clay soils was lifted. This rock had not been occupied during the previous two winters (at least) and this was the first recorded occurrence of S. flagellum occupying the particular rock (though specimens had been located only metres away beneath other rocks on various occasions). The rock was exposed to all day sun and located some 850m from the nearest permanent water. Initially when the rock was lifted, there were no snakes sheltering beneath it. However within seconds, and while I was balancing the rock vertically, two gravid females, in rapid succession, emerged from around my feet onto the now exposed substrate where the rock had been resting. They both froze still on apparently realising that the rock had been 'removed'. On capture they were warm and very agile. Evidently the females had been basking in a layer of grass a short distance from the rock and upon being disturbed by my approach had attempted to retreat beneath their rock. Beneath the rock were two sloughs (which were from adult female S. flagellum), one quite old, the other more recent indicating that the rock had possibly been occupied for up to two months (based on the known sloughing times of S. flagellum in the field; Turner, 1989). The rock was replaced and females allowed to retreat beneath it.

The details of each visit to the site are as follows:

25 January, 1130hrs - Both females probably basking together (though not seen) before attempting to seek cover beneath a rock. The larger of the two was very glossy and appears to have sloughed recently. O/S (23ºC), TB=29.3ºC.

8 February, 1140hrs, 2105hrs - At 1140hrs both females were basking in direct body contact some 0.4m from the refuge in a grassy mat. S (28ºC), TB=29.4ºC. When revisited in the evening (at 2105hrs) both females were beneath the rock.

15 February, 1150hrs - Both females were observed basking some 0.6m from the refuge partly concealed in a grassy mat. They were intertwined and moved little during a 15min. observation period. Their heads were mostly concealed from view beneath body folds. S (25ºC), BT=27.8ºC.

22 February, 1045hrs - Both females were discovered beneath the rock in direct body contact. S (27ºC), BT=23ºC, RT=21ºC.

The females were removed and retained in captivity up until parturition. Their measurements were: SVL=300, 326mm, TL=40, 44mm, M=35.54, 33.90g. On the 30 February the first of these females produced a litter of five (two normal neonates and three early stage embryos; see Turner (1996, 1998b) for details). The second female produced a litter of two on the 7 March.

Several urates were located in substrate material around the refuge site (within 1m of the refuge). No faecal masses were located beneath the rock or at the basking site.

## Aggregation 3.

On the 8 January 1994 an aggregation of four adult females was discovered at the opening of a crevice (0.49 x 0.01m) formed in a large (0.71 x 0.65m) embedded basalt rock. The rock formed part of a small outcrop on an inclined slope leading down to the Darebin Creek (25m away) and had a northerly aspect. Sunlight was able to penetrate the first few centimeters of the nearly vertical crevice allowing females to bask at the opening without actually having to move out from the crevice and the remainder of the embedded rock was subject to all day sun. A

small piece of rock obstructing part of the opening was easily removed and slotted back into place, permitting specimens to be viewed more easily when situated lower down in the crevice. This particular rock crevice had been occupied by several adult *S. flagellum* in previous years and more recently had been occupied by an adult male-female pair the previous winter and early spring up until October. Prior to the discovery of the aggregation, the rock was last inspected on the 29 October (when the male-female pair were present) so the aggregation may have formed some time during November or December. While initially there were four in the aggregation, the handling of two of the females seemed to result in their disappearance and thus the observations below are of the two remaining gravid females.

The details of each visit to the site are as follows:

8 January, 1410hrs - The aggregation was first noticed when the posterior body (excluding the tail) of a female was seen protruding from the rock crevice. One was close to the movable piece of rock, while the other female was at the opposite end of the crevice. Another two adult females were located behind the movable rock. They were all in direct body contact with the female protruding from the crevice. Two of the females were handled and these were clearly gravid. O (approx. 25ºC), AT=31.8ºC, RT=21.9ºC.

16 January, 1010hrs - Only two gravid females (the two which were not handled on the previous visit) were present and both were well down the crevice. The specimens were in direct body contact and inactive. Rain had wetted the interior of the crevice. O/R (23ºC), AT=RT=21.0ºC.

23 January, 1430hrs - The same two females were present and were lodged deep in the crevice. They were not in body contact. The temperature probe in direct contact with one of the females recorded a temperature of 36.5ºC. S (27ºC), AT=43.2ºC, RT<35ºC.

29 January, 1705hrs - Both females were

visible deep in the crevice and in were body contact. They moved down further until completely out of view on being disturbed and remained there well into the evening. They appeared not to have moved when inspected later the same day at 2300hrs. Another gravid female (one of the two females initially in the aggregation) was located beneath a rock only 1.2m away. This rock had been inspected on each previous visit indicating that the female had only recently moved to it. O (20ºC), AT=26.1ºC. RT=25.5ºC.

5 February, 1000hrs - Both females were visible deep in the crevice; it was unclear whether they were in direct body contact. O (31ºC), AT=RT=23.6ºC.

13 February, 1045hrs - Both females were close to the opening of the crevice, in direct contact with each other and the removable piece of rock but not in direct sunlight. One of the females was clearly opaque while the other appears to have sloughed within the last week. O (30ºC), AT=33.2ºC, RT=24.3ºC.

20 February, 0942hrs & 1520hrs - At 0942hrs one female was seen with the posterior flank exposed directly to sun at the opening of the crevice AT=25.8ºC; the second female was in direct body contact with the basking female. On later inspection (at 1520hrs) both females had retreated down into the crevice. S (29ºC), RT=27.6ºC, AT=35.3ºC.

26 February, 1100hrs - Neither female was present and the crevice was crawling with ants. The ants were observed feeding on dried material adhered to the lower rock surface of the crevice where the females formerly resided. This material resembled residual material associated with parturition ('after-birth') as seen in captive specimens (pers. obs.). This would suggest that parturition had taken place during the previous week. O (28ºC).

2 March, 1000hrs - The first neonate for the season was located beneath a rock 2m away from the refuge site.

No faecal masses were located in and around the refuge but several urates were located.

## General features of the aggregations.

Pooling the data obtained from each of the aggregations reveals several trends. Temperature data indicates an association between temperature at the basking site and basking. The mean temperature at the basking site was $27.2\pm2.16$°C with range 24-31.8°C (n=13). All except one of the temperatures recorded when snakes were concealed fell below this range. When basking, females tended to be in direct body contact more often than not (contact 11 vs no contact 1; $\chi^2=$ 6.75, 1 df, P=0.009). When within refuges females also tended to be in direct body contact (contact 8 vs no contact 1; $\chi^2=$ 4.00, 1 df, P=0.044).

The observations of gravid females in the three aggregations share the following features: (i) all gravid females engaged in basking, either by exposing the posterior body while remaining inside the crevice or by completely moving out of the refuge to a nearby basking site in the grass layer; (ii) basking generally occurred early in day (i.e., morning rather than afternoon) before the maximum daytime temperature was achieved and not at all on cold days; these periods were spent in the refuge; (iii) during basking females were frequently in direct body contact; (iv) night activity away from the refuge was not observed and (v) there was little faecal material located in and around the refuge and basking site. Also when basking, gravid females tended to maintain relatively open postures (see Mirtschin, 1985). Thus the aggregations appeared to be stationary, with movements confined to the refuge and its immediate surroundings.

Each of these field observations has been recorded in captive gravid female *S. flagellum* (Turner, 1985, 1996, pers.obs. and also see discussion). Gravid female *S. flagellum* have been observed to emerge from refugia to bask beneath artificial lights (Turner, 1985)

and furthermore, when two or more gravid females are housed together they will often bask together in direct body contact (pers. obs.). In captivity, basking by gravid females commenced as early as 27 days after mating (pers. obs.).

## Other gravid female aggregations.

About one-half of all the gravid females (52%, 16 of 31) located in the field during the months November through to March were part of an aggregation. As the procedure of searching for snakes involved lifting rocks and inspecting cracks and fissures this figure needs to be interpreted with caution given this searching bias and the difficulties in detecting females basking away from refuges. In addition to the three aggregations described, a further three aggregations (one at Deer Park, two at Somerton- 20km north of Melbourne) comprising a total of seven gravid females were recorded however follow-up inspections were too infrequent to permit any detailed comparison. Each of these aggregations occurred in exposed, slightly elevated exfoliating basalt in grasslands. Two of the aggregations were discovered in mid-December while the third was discovered in mid-January. The limited observations of these aggregations are consistent with those aggregations described above.

## Occurrence of single gravid females.

The remaining gravid females located in the field during the months November through to March occurred singly and were not part of an aggregation (48%, 15 of 31). Of these, four were seen basking semi-exposed from a rock crevice while others were found beneath exposed shallow surface rock and one beneath a discarded sheet of vinyl. Gravid females maintained singly in captivity readily emerged from ground cover to bask beneath artificial lights (Turner, 1985, 1996, pers. obs.).

## DISCUSSION

Existing accounts of gravid female aggregations of Australian elapid snakes are few but

enable a comparison with *S. flagellum*. Sault (1977) recorded an aggregation of "at least 30" basking adult ("at least 5ft") *Pseudechis porphyriacus* sometime during the period 26 December-3 January and an aggregation of "at least 10" basking adult ("all about 2ft long") *Austrelaps ramsayi* observed several times during the period 16-17 February. The reproductive status of the snakes in these aggregations was not determined. Shine (1979, 1991) recorded aggregations of gravid female *P. porphyriacus* ranging in size from two to six individuals and occasionally non-gravid females were part of the aggregations. Females were observed to share the same night-time retreat and emerged together in the morning to bask. They were recorded from mid-December to mid-February. Shine (1979) also recorded *Austrelaps superbus* and *Suta dwyeri* aggregations, these being represented by single observations of aggregates. The *A. superbus* aggregation consisted of two gravid females "basking near brush pile" in early January. The *S. dwyeri* aggregation consisted of three gravid females and one adult male located under a rock in late February. Parturition in *P. porphyriacus, A. superbus* and *S. dwyeri* occurs in late summer or early autumn (February-April; Shine, 1977). These accounts share some similarities with the observations of *S. flagellum* in that most involved gravid females basking, that the basking was based around or close to a refuge utilised by the snakes, and aggregations were recorded from mid-December up until the known parturition times for the species. Fyfe and Booth (1984) recorded aggregations of *S. flagellum* during summer months stating that they typically consisted of one sub-adult (sex?), an adult female, or an adult (male-female) pair. They did not mention the occurrence of gravid female aggregations during this or any other period however.

### Why do gravid female *S. flagellum* bask?

The observations of basking indicate that gravid female *S. flagellum* actively seek exposure to higher daytime temperatures compared to non-reproductives. They suggest that temperatures within the refuge are not always sufficiently high for gravid females and thus are supplemented by basking. In many (diurnal) viviparous reptiles gravid females have been observed to bask more than non-reproductives i.e., juveniles, adult males, non-gravid females (Shine, 1979, 1980). Basking in gravid female reptiles has been demonstrated in some species to accelerate embryogenesis and hence reduce the length of the gestation period (e.g., Schwarzkopf & Shine, 1991). This would confer a definite advantage to females, particularly in temperate regions where parturition often occurs in late summer or early autumn with a relatively short time between parturition and the onset of winter inactivity (Weekes, 1933, 1935), as is the case for *S. flagellum*.

The observations of gravid female *S. flagellum* emerging from their refuge during daylight hours to bask are significant given that *S. flagellum* and other members of the genus *Suta* (e.g., *S. dwyeri*, Shine, 1979) are nocturnal and as such are typically found beneath cover during daylight hours (Rawlinson, 1965; James, 1979; Fyfe & Booth, 1984; Shine, 1988; Turner, 1989). *Suta flagellum* is known to engage in behavioural thermoregulation when concealed (Lillywhite, 1980). It might be suggested that gravid female *S. flagellum* emerge from cover to feed in addition to (or instead of) basking. This is unlikely however as captive specimens show a rather limited capacity to capture mobile prey in daylight (pers. obs.) and little faecal material was located around any of the refuge and basking sites in the field. Furthermore gravid females in the field moved very little and often had their heads concealed when basking. Other than gravid females, records of *S. flagellum* emerging from cover during daylight hours, in either the field or captivity, are few (see Valentic, 1993; Turner, 1998a). Among the other Australian nocturnal elapid species there do not appear to be any reports of gravid females emerging from cover to bask during daylight hours. Nocturnal "basking" has however been reported in gravid

females of the nocturnal elapid species *Cacophis squamulosus* and *Rhinoplocephalus nigrescens* (Webb & Chapman, 1983).

It is uncertain whether basking behaviour in gravid female *S. flagellum* puts them at an increased risk of predation (i.e., greater than if they had remained concealed). This uncertainty is due to the absence of any known predators of *S. flagellum*. It is notable that although gravid female *S. flagellum* were described as "basking", they were never observed to do so in completely open situations. Individuals were generally partly concealed in grassy mats or else only exposed part of their body from crevices. This partial concealment and lack of movement at the basking site would probably help them to remain fairly inconspicuous. *Suta flagellum* does have several rather elaborate methods of defence (Fyfe & Booth, 1984; Turner, 1984) though it is uncertain as to what kind of animals these might be effective against and they did not use these defensive displays when approached by human observers.

## Why do gravid females form small aggregations?

This question is beyond the scope of this work and therefore the discussion is kept brief. Two general hypotheses that explain the formation of gravid female aggregations are: (i) mutual attraction and (ii) refuge shortage (Graves & Duvall, 1995). These hypotheses distinguish between the social and asocial basis for aggregate formation. The mutual attraction hypothesis states that aggregations are formed as a result of individuals being attracted to other conspecifics. Various authors have suggested possible selective advantages of this hypothesis (e.g. Graves & Duvall, 1995) the two most common being predator protection and thermoregulation. The refuge shortage hypothesis states that aggregations are formed as a result of a shortage of suitable refuges. Gravid female aggregations of *S. flagellum* were located in above ground refuges which allowed snakes to avoid overheating and which also permit-

ted them to bask nearby or from the refuge itself. Such refuges did not appear to be common at either of the grassland sites. It may also be notable that the particular rocks utilised by some aggregations were those frequently occupied by conspecifics at other times of the year. However presently there is insufficient evidence available to distinguish between the two hypotheses in the case of *S. flagellum*.

## Feeding in gravid females.

Shine (1977, 1979, 1991) found that in many species of elapids gravid female snakes feed infrequently or not at all during the later half of the gestation period. Shine (1988) does not make any comment as to the frequency of feeding in gravid female *Suta* (presumably due to the small sample size) though the trend to feed infrequently or not at all in several allied genera would indicate that it is probably the case for *Suta*. The question arises as to whether this finding is a consequence of gravid females not engaging in foraging behaviour (due perhaps to reduced locomotor performance) to the same extent as non-reproductives, or whether they genuinely abstain from feeding for some other reason (e.g., females reach a critical weight at which feeding ability is impaired; Shine, 1977). In captivity, gravid female *S. flagellum* will typically feed right up until parturition (Turner, 1989). In the field, faecal material was scarce around the refuge and basking sites. Gravid females encountered in the field tended to produce uric acid waste products rather than faeces and moreover unexpelled faecal masses (which are externally visible when in the lower portion of the alimentary canal), were rarely observed in gravid females (12.5%; 2 of 16). Most gravid females collected from the field retained between 2-8 weeks up until parturition did not produce any faecal masses (Turner, 1996). On the basis of these observations it is suggested that the apparent lack of feeding in gravid female *S. flagellum* in the field is probably a consequence of their sedentary habit.

## Paucity of gravid female *Suta* in museum collections.

Shine's (1988) examination of museum specimens of the (then separate) genera *Unechis* and *Suta* found that a very low proportion of gravid females were represented in museum collections (2.2% of all adult females). On this basis he speculated that gravid specimens "may become extremely secretive, and perhaps select microhabitats where they are relatively invulnerable to human predation". The observations of *S. flagellum* described in this work would appear to confirm this in part. They certainly indicate that females exhibit behavioural changes as a consequence of being gravid. By emerging during daylight hours to bask, gravid females behave in a manner at odds with their behaviour at other times of the year and the behaviour of non-reproductives. However in doing so they actually become less secretive in that they emerge from beneath ground cover. This change however tends to makes them more difficult to locate (by human observers at least) due to their small size and the dense grassy ground layer they inhabit.

In summary the observations described in this work indicate that gravid female *S. flagellum* share several behavioural characteristics, namely aggregation formation and basking, in common with females of several of the larger diurnal Australian elapids. It remains to be determined to what extent these behaviours occur among other Australian elapid genera and the reasons for them.

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# A RECORD OF HIGH FROG SPECIES DIVERSITY FROM THE MITCHELL GRASSLANDS OF SOUTHWESTERN QUEENSLAND

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## INTRODUCTION

Frogs are often difficult to detect when conducting fauna surveys in the drier regions of Australia because many species only emerge for short periods following large rainfall events. These events are infrequent and generally unpredictable in nature, but once rain falls, access to survey sites usually becomes very difficult. Surprisingly, in situations when surveys have been conducted under ideal conditions in the arid zone, frogs were found to represent a substantial part of the total biomass of the native vertebrate community (Predavec & Dickman, 1993; Morton et al., 1993; Read, 1999).

The "Action Plan for Australian Frogs" (Tyler, 1997) highlights the urgent need for further surveys and research to be conducted on frog genera such as Cyclorana and Neobatrachus, which occur in seasonally arid regions (or 'arid zone') so that the conservation status of these groups can be adequately assessed. Mitchell grasslands form a sizable section of this zone, extending in a broad arc from northwestern Western Australia to western New South Wales (Fisher, 1999). The recent study conducted by Fisher (1999) is the only comprehensive broad-scale assessment of biodiversity within these typically flat treeless Mitchell grass (Astrebla spp.) tussock grasslands on cracking clay soils. The findings of this study suggest that this ecosystem remains relatively homogeneous throughout, generating a biota that is depauperate in plant and animal diversity, both at a local and regional scale (Fisher, 1999).

In this paper we report the frog species observed within a small area in the Mitchell grasslands of the Warrego River plains in southwestern Queensland.

## METHODS

Surveys were conducted on Offham station (27°32'S, 145°53'E) 75 km north of Cunnamulla in southwestern Queensland (Figure 1). The site lies on the Warrego River floodplains, which supports an extensive area of Mitchell grasslands within the Mulgalands bioregion (Wilson, 1999). Sheep and cattle grazing are the primary land use. The climate is characterised by hot summers and mild winters. Annual rainfall averages 352 mm with large rainfall events (>100 mm) more frequent in summer.

The region experienced relatively high rainfall over the summer period in 1996-97. Rain had fallen prior to our arrival on the 2nd February 1997, and a further 72 mm of rain fell overnight. This was followed by a further 36 mm on the 3rd February. We surveyed a 12 ha strip of land (600m by 200m) between 8-10pm on the 3rd and 4th February 1997. Conditions were overcast and humid on both nights but no rain fell.

Surveys were conducted along the edge of an alluvially derived sandhill (200 ha) within the Mitchell grasslands. Unlike the surrounding sparsely wooded grasslands, the sandhill supports an open cypress pine (Callitris spp.) and beefwood (Grevillea nematophylla) woodland with an understory of thorny saltbush (Rhagodia spinescens), introduced buffel grass (Cenchrus ciliaris) and spear grass (Aristida spp.). The heavy rains filled a number of gilgais (natural depressions) located in the transition zone between the clay soiled Mitchell grassland and the massive sands of the sandhill, providing temporary breeding pools for frogs. The larger of the three gilgais was fringed by mature coolibah trees (Eucalyptus coolabah). There

was also a low lying area containing numerous smaller gilgais within the Mitchell grasslands, marking the start of a drainage system lined by gidgee trees (*Acacia cambagei*) and lignum (*Muehlenbeckia florulenta*). All waterbodies within the site are ephemeral, the largest gilgai usually holds water for 3-4 months following rain. However, there is a flowing artesian bore nearby, which feeds two boredrains that are located within 400 m of the survey site.

Individual frog species were identified from male choruses and actively searched for by torchlight. Captured frogs were identified using the keys and descriptions in Cogger (1994). Nomenclature and taxonomic order used in this paper follow Ingram *et al.* (1993). No systematic counts of frogs were conducted, rather species abundance was assessed subjectively from general observations of individuals, their distribution within the site, total chorus intensity and frequency of calling.

Rankings were:

Abundant – many sightings, widespread, loud almost constant chorus

Common – many sightings, mostly at larger pools, breaks in chorus

Uncommon – occasional sightings, limited to 1-2 pools, calls less frequent

Rare – several sightings, 1 location only, calls infrequent or absent.

## RESULTS

Fifteen species of frog were found in the 12 ha survey site over the 2 nights (Table 1). All species were distinguished by their calls, except for *Cyclorana cultripes*, of which only one non-calling individual was found. *Cyclorana platycephala*, *Neobatrachus sudelli*, and *Notaden bennettii* were not heard on the second night of the survey, despite similar intensity of searching on the two nights.

**Table1. Frog species recorded at Offham Station, Southwestern Queensland between the 3rd and 4th February 1997.**

| Species | Common Name | Species Abundance |
|---|---|---|
| Hylidae | | |
| *Cyclorana cultripes* | Desert Collared-Frog | Rare, one found on edge of sandhill. |
| *Cyclorana novaehollandiae* | EasternSnapping-Frog | Abundant. |
| *Cyclorana platycephala* | Water-Holding Frog | Uncommon. |
| *Litoria alboguttata* | Green striped Frog | Common. |
| *Litoria caerulea* | Green Treefrog | Common near large coolibah trees. |
| *Litoria latopalmata* | Broad-Palmed Rocketfrog | Common. |
| *Litoria peronii* | Emerald-Spotted Treefrog | Common near large coolibah trees. |
| *Litoria rubella* | Naked Treefrog | Abundant. |
| Myobatrachidae | | |
| *Limnodynastes fletcheri* | Barking Frog | Uncommon?, difficult to hear. |
| *Limnodynastes ornatus* | Ornate Burrowing-Frog | Abundant. |
| *Limnodynastes tasmaniensis* | Spotted Marshfrog | Abundant. |
| *Neobatrachus sudelli* | Eastern Metal-Eyed Frog | Rare, Mitchell grassland gilgais only. |
| *Notaden bennettii* | Holy Cross Frog | Uncommon, drainageline under gidgee trees. |
| *Uperoleia capitulata* | Desert Gungan | Abundant. |

## DISCUSSION

In general, biological surveys are conducted over considerably larger areas, but it would appear that we have recorded one of the highest levels of frog species diversity known for a single site within the semi-arid zone. This is rather incongruous considering the apparently homogenous nature of the Mitchell grasslands (Fisher, 1999). High local habitat heterogeneity resulting from the presence of the sandhill and occurrence of gilgais providing temporary breeding pools for frogs appear to have greatly increased frog diversity within this normally species depauperate ecosystem. Fisher (1999) found a similar pattern for avian fauna within these grasslands, where local increases in species richness were generally associated with isolated woodland areas.

It is improbable that the boredrains benefit frogs in the survey area because the area surveyed is located close to the bore head. Consequently, the water in each boredrain remains clear and relatively warm (approximately 25-28°C) favouring predatory species including the mosquito fish (*Gambusia holbrooki*), spangled perch (*Leiopotherapon unicolor*) and long-necked turtles (*Chelodina longicollis*). In spite of intensive searches while studying long-necked turtles, only the occasional adult frog has been observed in or near these boredrains. No frog spawn or tadpoles have been found.

There is little published survey information on the frog fauna of the Mitchell grasslands. Brooker and Caughley (1966) recorded 9 species of frog from "Gilruth Plains", which is also located on the Warrego River plains approximately 100 km to the south of this site. All of the species recorded by Brooker and Caughley (1966) were recorded during this study. Extensive surveys conducted within the Channel Country biogeographical region in far western Queensland detected all species recorded in our study, along with a further 8 frog species (McGreevy, 1987; MacFarland, 1992). This region contains substantial areas of Mitchell grasslands (Fisher,

1999), but not all of these species were found within this ecosystem.

According to Cogger (1994) and Ingram and Raven (1991) there are 18 species of frog that have described distributions incorporating our study site. All frogs found during this survey were within their described range for at least one of these references. The three species we failed to find were *Cyclorana verrucosa, Crinia parinsignifera* and *U. rugosa*. Considering the small area surveyed when conditions were ideal during this study, it is possible that these species occur in the region but were not present on the survey site. Alternatively, we may not have been able to distinguish these species from related species or simply could not hear them if they were in low abundance due to the noise of the total chorus.

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Figure 1. Location of study site in southwestern Queensland (shading denotes the Mitchell Grasslands). Insert displays the distribution of the Mitchell Grasslands in Australia
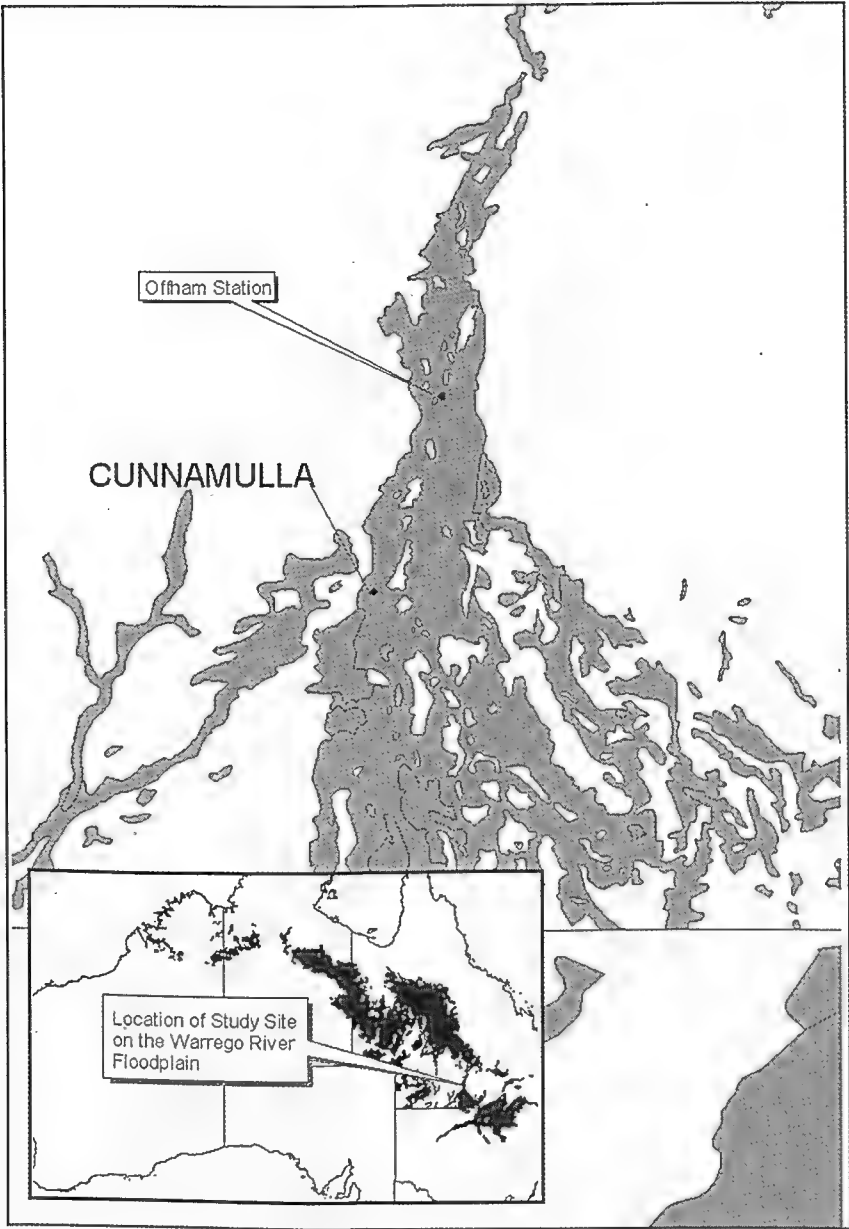
# AN INSTANCE OF HYBRIDISATION BETWEEN TWO BROADLY SYMPATRIC *LIMNODYNASTES* SPECIES.

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## ABSTRACT

Explosive anuran breeding assemblages often result in interspecific mating. This may result in the formation of natural hybrids, and is common along shared borders of allopatric species. Interspecific mating of broadly sympatric species is less frequently documented. Collection of an apparent hybrid between *Limnodynastes dumerilii* and *Limnodynastes tasmaniensis* in Western Sydney prompted investigation of the potential for interbreeding success between them. Only female *L. tasmaniensis* oviposited eggs. However, the interspecific mating between *L. dumerilii* and *L. tasmaniensis* produced fewer eggs, with lower viability than intraspecific coupling. Few naturally occurring hybrids indicate that such animals have reduced fitness.

## INTRODUCTION

Typically anurans that utilise ephemeral wetlands as oviposition sites (eg; *Cyclorana*, *Limnodynastes*, *Litoria rubella*, *Litoria rothii*, and *Neobatrachus*) tend to breed explosively (Duellman and Trueb, 1986). Males move to selected calling sites, that are often species specific (Tyler, 1999). From these positions they call to attract mates. Any individuals encounted at these sites are usually amplexed, tightly clasped and defended (Pough *et al.*, 1998). Vocalisation serves to identify an animal (taxonomically and spatially), and location may also assist females in species identification and mate selection (Tyler, 1999). Species discrimination by males may, in some cases, be aided by tactile cues such as animal size and skin texture (Duellman and Trueb, 1986). This is an especially important aid in species recognition among sympatric and synchronously breeding congeners, however, occasional mistakes occur (Tyler, 1999).

Hybridisation is often reported in allopatric anuran species, and when the two parental forms are genetically compatible, stable hybrid zones may be formed (Gollmann, 1991; Gollmann & Gollmann, 1994). In Australia, allopatric hybridisation has been reported in several species. These include *Geocrinia laevis* and *Geocrinia victoriana* in southeastern Australia (Littlejohn *et al.*, 1971; Littlejohn and Watson, 1985; Gollmann, 1991), the northern and southern call races of *Limnodynastes tasmaniensis* (Littlejohn and Roberts, 1975) and members of the *Litoria ewingi* complex (Littlejohn and Watson, 1985).

The occurrence of hybridisation between broadly sympatric species has received little attention (Gerhardt and Schwartz, 1995). In southwestern Utah and northwestern Arizona, hybridisation between sympatric *Bufo microscaphus* and *Bufo woodhousii* was observed to be relatively stable geographically (Sullivan, 1995). In Australia, mismatched amplexic pairs are occasionally observed (Tyler, 1999; C. Schell *pers. obs.*) although the offspring of such matings are rarely encounted. Based on the observation of an apparent hybrid between the two broadly sympatric *Limnodynastes dumerilii* and *Limnodynastes tasmaniensis* we attempted to hybridise them. These species are sympatric over much of Tasmania, Victoria and the east coast of New South Wales (Cogger, 2000).

*Limnodynastes dumerilii* is a large, robust frog that grows to 70mm snout - urostyle length (SUL). Colouration is grey and brown dorsally, blue, yellow and black laterally, and pale yellow to cream ventrally. Skin on the dorsal regions may be smooth, or contain slightly raised, rounded warts. Large glands are present on the tibial region and metatarsal

tubercles are also present. *Limnodynastes tasmaniensis* is a smaller species growing to around 45mm SUL. The body is dorsoventrally compressed and dorsal colouration consists of olive to rich leaf green blotches on a pale brown background. They are pale yellow to white ventrally with smooth skin. Both *L. tasmaniensis* and *L. dumerilii* have similar habitat requirements (Cogger, 2000).

## METHODOLOGY

Three fecund females (eggs visible through the lateral skin) and three sexually mature males of both *L. dumerilii* and *L. tasmaniensis* were collected from the frog assemblage associated with an ephemeral swamp on the Richmond campus of the University of Western Sydney (6278375N, 288375E) in December, 1999. In separate one litre plastic containers, pairs of frogs in the following combinations were placed: 2 x *L. tasmaniensis*, 2 x *L. dumerilii* and 2 mixed pairs (*L. dumerilii* + *L. tasmaniensis*). One mixed pair consisted of a male *L. dumerilii* and female *L. tasmaniensis* and the other pair was the reciprocal cross. Each container also contained 300mL of dechlorinated water and was covered with muslin to restrict frog escape but also to allow airflow. All pairs were contained within a controlled environment (23ºC, 12 hour photoperiod). Frogs were separated 1 hour after cessation of reproductive behaviour and females were visually inspected through the lateral skin for retained eggs. Deposited eggs were counted and then allowed to develop in clean dechlorinated water to determine hatching viability. Adults were released at point of capture after a maximum of 48 hours in captivity. Twenty *L. tasmanensis* and twenty *L. dumerilii* x *L. tasmanensis* hybrids were randomly collected from among the hatched fry and allowed to metamorphose. Metamorphic dimensions (snout urostyle length, tibia length and gape width) were obtained and analysed using ANOVA from these metamorphs and statistical analyses were undertaken using *Statistica*, Version 5.5, 1999 edition.

## RESULTS

All males amplexed but the *L. tasmaniensis* male had difficulties clasping the larger *L. dumerilii* female. Only *L. tasmaniensis* females oviposited and there was no indication that oviposition was attempted by the female *L. dumerilii*. Regardless of inter- or intra-specific coupling, oviposition was preceded by females stretching their forelegs forward above the waters surface, followed by a rapid downward sweep. This caused bubbles to pass under the females body and they emerged between the hind legs where they were caught within a viscous substance liberated from the females cloaca. The trapped bubbles formed the bubble nest characteristic of this genus. The process took <1 second. During this time, contortions of the female's ventral surface provided downward pressure on the male's nuptial pads, and he responded by releasing sperm. This was accompanied with complex leg movements of the male (similar to those observed by Tyler, 1999) that partially trapped eggs expelled from the females cloaca and may have facilitated fertilisation by keeping them in close proximity to his cloaca. During *L. tasmaniensis* coupling, the cloacae were positioned to allow minimal external distance between the two orifices, while the cloaca of the *L. dumerilii* x *L. tasmaniensis* pairing were more than 1cm apart, presumably due to body size differences and body orientation (*L. dumerilii* = 59mm vs *L. tasmaniensis* = 39mm). The result was less efficient egg trapping and reduced egg mass formation efficiency as the male *L. dumerilii* could not properly orientate its body and legs to trap the air bubbles (mentioned previously) or the liberated eggs. The *L. tasmaniensis* matings produced more eggs of higher viability (n = 809, viability = 91.1%; n = 694, viability = 92.7%) than the hybrid cross (n = 596, viability = 26.8%), however, only in the interspecific mating did the female retain eggs.

Hybrid tadpole tooth rows had the formulae:
$$\frac{2\ \underline{2}\ 2}{1\ \underline{2}\ 1}$$ at Gosner stage 25 (Gosner, 1960)

and had two tooth rows less on either side of the upper mandible than both of the parental species. At stage 46 (Gosner, 1960) hybrid metamorphs were significantly larger than *L. tasmaniensis* metamorphs in all measured features (P<0.01) with greater variation in gape width (Table 1). Hybrids had an average larval period of 214 days (based on 20 hybrid specimens) and resembled *L. tasmaniensis* in dorsal colouration (metallic green spots on a fawn background) and *L. dumerilii* in stature and lateral colouration after metamorphosis (Plate 1). The *L. dumerilii* tibial gland was prevalent on hybrids, together with the large inner metatarsal tubercle, both of which were absent on *L. tasmaniensis* metamorphs.

## DISCUSSION

Although all females contained pre-ovulatory eggs, only *L. tasmaniensis* oviposited. All males amplexed. Female *L. tasmaniensis* displayed no obvious signs of distress or desire to escape foreign males. This may indicate poorly developed female mate selection in *L. tasmaniensis*. In contrast to *L. tasmaniensis*, *L. dumerilii* females struggled to be released from foreign males, although they did not vocalise.

The hybrid cross produced fewer eggs than the *L. tasmaniensis* crosses and the female involved in the hybrid mating retained eggs after oviposition while other females apparently did not. This may be a form of cryptic female choice, whereby the females 'cryptically' choose which individuals sire their offspring, even when their preferred copulatory partner is overrun by either male to male competition or sexual coercion. By retaining eggs, it is possible that the female may be ensuring that future encounters with 'desirable' copulatory partners may be exploited soon after the cessation of the interspecific coupling. This phenomena has been reported in the hybridogenic *Rana lessonae / Rana esculenta* complex where females adjusted their clutch size as a result of male desirability (Reyer *et al.*, 1999).

Size may play an important role in prezygotic

isolating mechanisms and while it did not inhibit *L. tasmaniensis* females from reproducing with foreign individuals, the males were apparently less able to clasp the relatively larger foreign females. Larger females may select 'fitter' individuals as mates and, therefore, reject the relatively smaller *L. tasmaniensis*. The nuptial grasp and forefoot position during mating may also differentiate species. This is evident in *Limnodynastes peronii* where males have sharp bony projections under the skin of their innermost digit on their forelimb. These spurs are used in male to male interactions and for clasping females during amplexus (C. Schell *pers. obs.*) and within the genus are unique to *L. peronii*. Although absent in male *L. dumerilii*, their long forelegs enable males to encircle the female's rear quarters during amplexus, a feat the smaller *L. tasmaniensis* could not achieve.

Hybrid egg viability was also considerably lower than that of the intraspecific coupling. This may result from parental morphological characteristics. Although similar in reproductive behaviour, size differences may have inhibited efficient fertilisation between the species by altering the alignment of the interspecific pair during oviposition, resulting in unfertilised eggs. Unlike the intraspecific pairs, during oviposition the smaller *L. tasmanensis* expelled eggs that often did not reach the cloaca of the larger *L. dumerilii*. Additionally, bubble nest formation efficiency by the female was reduced as a result of pair orientation that resulted in 'lost' eggs. In addition, postzygotic isolating mechanisms may have reduced viability, such that errors in development may have resulted from mismatched chromosomes or incompatible genes. Some eggs did not develop (i.e. were not fertilised), while others may have ceased development due to lethal chromosome assortment. The average larval period was 214 days, which was intermediate between *L. tasmaniensis* (90-150 days, Martin, 1965) and *L. dumerilii* (365-450 days, Davies, 1991).

Tooth row morphology of the tadpoles differed from their parental phenotypes. This

would have been a developmental error due to unbalanced genes. There was also a greater degree of morphological variation in gape width observed in the hybrid metamorphs than in *L. tasmaniensis*. This may be a consequence of genetic instability. Since *L. dumerilii* (2n = 24) and *L. tasmaniensis* (2n = 22) chromosome numbers differ (Mahony, 1986) such hybrids may be sterile due to non-disjunction during meiosis (Davis *et al.*, 1990).

Despite observations of interspecific amplexus in the wild and successful reproduction in captivity, of 5998 individuals pitfall trapped from the site in 1999 - 2000 only one hybrid was encountered. This indicates that reduced fitness is not restricted to fertilisation and early development, but probably indicates low survivability and fertility of the hybrids.

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**Figure 1:** *Limnodynastes tasmaniensis* x *Limnodynastes dumerilii* **hybrid metamorph.**



**Table 1:** **Metamorphic dimensions and descriptive statistics of** *Limnodynastes tasmaniensis* **and hybrid** *L. tasmaniensis* **x** *Limnodynastes dumerilii* **(SUL = snout-urostyle length, GW = gape width, TL = tibia length). Measurements are in centimetres.**

|  |  | Dimensions | | |
|  |  | SUL | GW | TL |
| --- | --- | --- | --- | --- |
| *Hybrids* | mean | 1.901 | 0.915 | 0.835 |
| *n=20* | variance | 0.0088 | 0.0545 | 0.0024 |
|  | SE | 0.021 | 0.052 | 0.011 |
|  |  |  |  |  |
| *L. tamaniensis* | mean | 1.354 | 0.595 | 0.587 |
| *n = 20* | variance | 0.0084 | 0.0029 | 0.0029 |
|  | SE | 0.021 | 0.012 | 0.011 |

# REDISCOVERY OF A GREEN AND GOLDEN BELL FROG POPULATION IN THE SOUTHERN TABLELANDS

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## ABSTRACT

Extensive flora and fauna surveys were conducted in the Queanbeyan region of New South Wales in March and April 2000. During this survey a mixed size Green and Golden Bell Frog (*Litoria aurea*) population was located in a wetland on the Molonglo River floodplain. Discovery of this population provides clear evidence that *L. aurea* is present in small numbers in the Southern Tablelands and is not extinct from this region as originally thought.

## INTRODUCTION

In recent years a number of Australian frog species have suffered rapid, often mysterious, population declines (White, 1995; White & Pyke, 1996; Osborne *et al.*, 1996; Mahony, 1999).

*L. aurea* was formerly widespread in coastal areas between Northern NSW and the east Gippsland area of Victoria; there was also a substantial population in the Southern Tablelands of NSW (Barker & Grigg, 1977; White, 1995; Gillespie, 1996; Osborne *et al.*, 1996; Thomson *et al.*, 1996; White & Pike, 1996; Mahony, 1999). The former distribution and decline of this species has been well documented in comparison with many other frog species (Gillespie, 1996; Osborne *et al.*, 1996; White & Pyke, 1996; Mahony, 1999).

Since 1990, *L. aurea* is thought to have disappeared from at least 113 locations in NSW, with the population size at some remaining sites also showing strong declines (White & Pyke, 1996). At present there are only 38 known populations of *L. aurea*, 19 of which occur in the Sydney Basin (Mahony, 1999). All other previously identified populations occur in coastal regions (Tyler, 1997) below 150

metres (ADH) between Newcastle and Wollongong (Osborne *et al.*, 1996; Mahony, 1999). While it is unclear exactly when *L. aurea* began to decline, there have been no confirmed sightings of *L. aurea* in the Southern Tablelands since 1980 (Osborne *et al.*, 1996).

A number of reasons have been proposed for the decline of *L. aurea* and other frog species throughout Australia. Predation by the introduced Mosquito Fish (*Gambusia holbrooki*) may have reduced frog populations in some, but not all areas (Morgan & Buttemer, 1996; Gillespie & Hero, 1999; Lewis & Goldingay, 1999). Reduced water quality, habitat destruction, population isolation (Mahony, 1999) and drought (Osborne *et al.*, 1996) have all been proposed as possible reasons for the regional declines of *L. aurea* populations. There is also mounting evidence to suggest that the rapid decline of many frog species including *L. aurea* is the result of infection by chytrid fungus (*Batrachochytrium* sp.) (Berger *et al.*, 1998, 1999; Bishop, 2000; Santiago & Merino, 2000; Bosch *et al.*, 2001). Mortality as a result of increasing UV-B radiation (van de Mortel & Buttemer, 1996) and potential synergistic interactions between UV-B radiation and disease (Kiesecker & Blaustein, 1995) are also being investigated.

We conducted surveys in the Southern Tablelands, between the NSW/Canberra border at Queanbeyan and Molonglo River floodplain in order to assess habitat type and integrity, floral and faunal diversity and identify threatened species occurring in the region. As part of these surveys we conducted comprehensive searches of likely frog habitats to assess the presence of frogs in the area.

## METHODS

Surveys were conducted in the Queanbeyan region between the 23rd to the 26th of March and on the 3rd of April 2000. Weather during the main survey period was cold and wet with average mean daily temperatures between 15 and 18º C. The April survey was conducted in fine warm conditions.

The study area was delineated during a site inspection into habitat types on the basis of dominant vegetation. These included woodlands, grassy woodlands, grasslands, improved pastures and swamps. Frog searches were conducted around dams, sediment traps, drainage lines, pools, creeks and swamps within each of these habitats (Table 1). Opportunistic searches were also conducted in selected areas of a five kilometre stretch of the Molonglo River near Hoskinstown.

Call play back, visual searches and frog chorus surveys were employed to locate and identify frog species at each of the eight sites. Call play back of L. aurea and L. raniformis choruses were conducted nightly for up to five minutes followed by a period of five minutes waiting for a response. Extensive visual surveys involving log rolling and inspections around areas of likely habitat were conducted during the day. Dusk and dark frog chorus surveys, were conducted for five minutes at each site. These methods were used to collect qualitative data rather than quantitative.

Species were identified from Cogger (1996). Sex of captured individuals was determined by the presence of nuptial pads on the on the inner surface of each thumb. Only a few L. aurea were caught to verify the species and their sex.

## RESULTS

Nine frog species were identified during the surveys (Table 2). The Common Eastern Froglet (Crinia signifera) was the most common and widespread species in the region occurring at seven of the eight sites. Spotted Grass Frogs (Limnodynastes tasmaniensis) were also relatively common. Of most

significance was the identification of a L. aurea population on the Molonglo River floodplain (Site 8). Twelve individuals were identified ranging in size from adult to recently metamorphosed individuals of both sexes. Subsequent research by Will Osborne and Sam Patmore has marked 120 adult sized L. aurea in suitable habitat between Site 8 and the Molonglo River with early population estimates being in the order of a few hundred individuals (W. Osborne and S. Patmore, pers. comm.).

### Description of L. aurea Green and Golden Bell Frog Habitat

Site 8 is located on south eastern edge of the Molonglo River floodplain. The vast majority of this floodplain is subject to agricultural activity, mainly cattle and sheep grazing. Vegetation on the higher areas is characterised by a mixture of improved, semi-improved and native pastures.

The floodplain is transversed by a series of minor tributaries and prior stream remnants, which create a series of shallow pools through the summer months and carry intermittent flows during rain events. Much of the low-lying areas are subject to frequent inundation, which is reflected in the dominant flora at the site.

Phalaris (Phalaris aquatica), Tall Sedge (Carex inversa) and Tussock Grass (Poa labillardieri) form tall grasslands in low-lying areas around the site. Prior stream remnants and minor tributaries contain Typha sp. and aquatic plants including Elodea (Elodea canadensis) and Milfoil (Myriophyllum sp.).

The majority of L. aurea individuals were found around a small water-filled depression, approximately ten metres long and two metres wide. The water was still, with depths generally less than thirty centimetres at the time of survey, containing abundant aquatic vegetation (Milfoil) and filamentous algae. While little is known of the hydrological regime of the area, the lack of terrestrial vegetation within the depression to a height of 0.5 metres suggests that it regularly contains

water, with depths fluctuating throughout the year.

The paddock is periodically grazed by cattle and sheep and had been rested prior to our survey, although cattle were present during the subsequent survey of this site on the 3rd of April.

## Table 1. Description of sites surveyed.

| Site No. | Description | Area (ha) | Dominant Vegetation |
|---|---|---|---|
| 1 | Sediment Dam | <0.25 | Carex appressa, Eleocharis sp. and Phalaris aquatica. |
| 2 | Sediment Dam | <0.25 | Carex appressa, Eleocharis sp. and Phalaris aquatica. |
| 3 | Dam | <0.25 | Juncus sp. and Phalaris aquatica. |
| 4 | Stony Creek Still shallow water | 0.5 | Ranunculus lappaceus, Juncus usitatus, Cyperus eragrostis, Schoenus apogon and Phalaris aquatica. |
| 5 | Farm Dam | <0.25 | Improved pasture, with no aquatic vegetation. |
| 6 | Whiskers Creek Slow moving to still water. | 1 | Juncus usitatus, Cyperus eragrostis, Schoenus apogon, Eleocharis sphacelata, Carex appressa and Phalaris aquatica. |
| 7 | Drainage Depression. | <0.5 | Cyperus eragrostis, Eleocharis sphacelata, Carex appressa and Phalaris aquatica. |
| 8 | Swamp with prior tream remnants and farm dams. | 100 | Phalaris aquatica, Carex inversa, Cyperus era grostis, Schoenus apogon, Eleocharis sphacelata, Carex appressa, Poa labillardieri, Elodea canadensis and Myriophyllum sp. |

## Table 2. Survey results.

| Scientific Name | Common Name | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Crinia parinsignifera | Plains Froglet | | | * | * | | | * | * |
| Crinia signifera | Common Eastern Froglet | * | * | * | * | | * | * | * |
| Litoria aurea | Green and Golden Bell Frog | | | | | | | | * |
| Litoria lesueuri | Lesueur's Frog | | | | | | | | * |
| Litoria verreauxii | Whistling Tree Frog | * | * | | | | * | | * |
| Lyimnodynastes peronii | Striped Marsh Frog | | | | | | | | * |
| Limnodynastes tasmaniensis | Spotted Grass Frog | * | * | * | * | | | | * |
| Uperoleia laevigata | Smooth Toadlet | | | | * | * | | | |

* Denotes species presence.

## DISCUSSION

The discovery of an *L. aurea* population in the Southern Tablelands increases the number of known populations to 39 and is the first population to be identified in the Southern Tablelands and at an altitudes higher than 150 metres (ADH) since 1980.

The primary causes for the decline of *L. aurea* populations in the Southern Tablelands are uncertain. While agricultural and residential developments may have resulted in the destruction of suitable habitat is some areas, the species was able to utilise modified habitats and was often found in farm dams and artificial wetlands in urban areas (Osborne *et al.*, 1996; Tyler, 1997).

Mosquito Fish (*Gambusia holbrooki*), which are known to kill *L. aurea* tadpoles (Pyke & White, 2000) and may have been responsible for the loss of some *L. aurea* populations (Osborne *et al.*, 1996; Tyler, 1997; Lewis & Goldingay, 1999; Mahony, 1999), are believed to be absent from this site. However, it should be noted that Mosquito Fish are also absent from a number of sites formerly supporting *L. aurea* on the Southern Tablelands (Osborne *et al.*, 1996).

Chytrid fungus has been identified in two dying *L. aurea* individuals found at this site following their rediscovery (W. Osborne, pers. comm.). The occurrence of this population in spite of the presence of chytrid fungus may be a function of its large size, which would allow the population to recover more quickly following die offs. Interaction between chytrid survival and virulence and high heavy metal concentrations in the Molonglo River (Yarrowlumla Shire Council, 1997) warrants further investigation.

The site contains a series of interconnected wetlands as well as the Molonglo River which would provide permanent water during drought conditions, such as those experienced during the early 1980's. This also allows adult individuals to migrate in response to cattle disturbance.

The habitat of this rediscovered population shares a number of similarities with past and present *L. aurea* habitats recorded on the Southern Tablelands and elsewhere in NSW (White & Pyke, 1996; Tyler, 1997). It is open, with a substantial area of tussock grasses that appears to provide diuranal shelter sites and over-winter sites. There are areas of shallow ephemeral water, containing large amounts of aquatic vegetation such as *Typha* sp., as well as permanent water bodies. Ephemeral water bodies are expected to be free of predatory fish species such as Mosquito Fish, making them suitable breeding sites (White & Pyke, 1996).

It is unclear what effects the present rotational grazing regime is having on the population, although the species has persisted and is capable of breeding at the site under the current management system. The location and characteristics of other likely habitats along with the distribution of *L. aurea* across the floodplain are currently being investigated by Sam Patmore and Will Osborne.

This survey was conducted over a relatively small area over a short period of time and fails to answer several key questions. The survey was conducted at the end of the *L. aurea* breeding season so breeding and tadpole activity was not observed. However, the presence of recent metamorphs would indicate that the population is breeding at the site. Physiological characteristics of the water bodies within this habitat were not assessed which should be a priority of future investigations. In addition it is important to determine the full extent of infestation by chytrid fungus or other pathogens.

Some of the management actions for frogs that are recommended by Tyler (1997) are pertinent to this population and useful in the study of *L. aurea* in a wider sense. Specifically, these are determining the ecological requirements for sustaining viable populations in the wild and determining the impact of various threats including *G. holbrooki* and other predatory fish species on tadpoles and eggs.

The former is of particular interest as this population appears to have has continued in relative isolation and without any apparent intervention from wildlife managers. Detailed studies of the attributes of their habitat at this site may prove invaluable as wildlife managers attempt to enhance and preserve other *L. aurea* sites in eastern NSW.

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# THE GREAT DESERT SKINK (*EGERNIA KINTOREI*) IN WESTERN AUSTRALIA: DISTRIBUTION, REPRODUCTION AND ETHNO-ZOOLOGICAL OBSERVATIONS

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## INTRODUCTION

Despite its large size and a wide geographic distribution, the Great Desert Skink, *Egernia kintorei* (Stirling & Zietz, 1893), is known from very few sites in Western Australia. The Western Australian Museum held just nine specimens of *E. kintorei* from five widely scattered localities in Western Australia. The most recent W.A. specimen was collected in 1967. The species status was listed nationally by Cogger *et al.* (1993) as 'Vulnerable'. This note reports on recent captures of the species in the Gibson Desert, data on its reproduction and ethno-zoological information provided by local Pintupi people.

## METHODS

We made two·trips from Karilywara Community on the eastern edge of the Gibson Desert Nature Reserve, in search of specimens of *E. kintorei* and the Woma Python (*Aspidites ramsayi*). On the first trip, a small faded specimen of *E. kintorei* loaned from the Western Australian Museum was shown to local Aboriginal (Pintupi) people. Several of the older ladies in the community recognised the species instantly, known in the Pintupi dialect as 'tjakurra', or less commonly as 'tjalapa'. The name 'tjakurra' (or 'tjakura') is used widely by desert Aboriginal people (Baker *et al.*, 1993; McAlpin, 1998). It was known to be abundant near a rockhole 45 km to the south-east of Karilywara Community.

A search of this location on June 19 1997 found several old burrow systems, each with a communal faecal site and one entrance marked by a large, elevated soil mound. Two burrow systems with fresh activity were excavated after the surrounding vegetation was burnt. Reptiles that fled from the burrow

systems during·this firing included the gecko *Heteronotia binoei* and the skink *Ctenotus pantherinus*. The first burrow yielded no *E. kintorei*, but the second contained a male, a female and a subadult. All three were taken to Perth but the female later died of an injury inflicted during excavation. All three individuals were then lodged with the Western Australian Museum (WAM 129881, 131046-7).

A second trip on December 15 1997 resulted in the capture of another pair of adult *E. kintorei* and a subadult; all were sharing the same burrow system. Woma Pythons and Goulds Sand Goanna (*Varanus gouldii*) were found to be sympatric with *E. kintorei* and were recovered from adjoining complex burrow systems during both visits. The three *E. kintorei* were taken back to Perth and maintained in large aquaria. Observations on their breeding are based on these captive individuals and unpublished data provided by Glenn Shea from his dissections of Museum specimens.

## DISTRIBUTION AND HABITAT IN WESTERN AUSTRALIA

*Egernia kintorei* has been collected from few and widely scattered locations in Western Australia. Table 1 shows the collection sites of Museum specimens from Western Australia and the sites of collected specimens reported here. Also included are details of a subadult *E. kintorei* collected by Eric Pianka in 1967, the only one obtained during his capture of 5821 desert lizards over a 20 year period (Pianka, 1986: 157). This specimen is lodged at the Los Angeles County Museum (LACM 56512).

Capture sites in W.A. are mapped in Figure 1. The type specimen (lectotype; Mitchell, 1950)

was collected by members of the Elder Scientific Exploring Expedition, south of the Barrow Range, W.A. Stirling and Zeitz (1893) noted that it was obtained from a young Aboriginal girl when the Expedition caused her kin to flee; hardly surprising considering the party was accompanied by over 40 camels! Lindsay (1893) recorded the incident in his journal on September 3, 1891.

Otto Lipfert collected six specimens along the Canning Stock Route in the 1930s, while the other three W.A. specimens held by the Western Australia Museum were collected in 1963 and 1964. Previous collection sites in WA are situated in the Great Sandy or Great Victoria Deserts. The specimens reported here are the first recorded from the Gibson Desert.

Few habitat data are available for Western Australian specimens, but the localities suggest they were obtained from sandy habitats. Certainly, the preferred habitat of the species in the NT is sandplain and interdunes with sandy or sand-loam soils (McAlpin, 1997). The specimens reported here came from two sites on gently undulating sandplain of deep red sands with a surface cover of fine lateritic 'buckshot' gravel, characteristic of vast areas of the Gibson Desert. The vegetation was dominated by the hummock grasses ('spinifex') *Triodia basedowii* and *T. schinzii*. This habitat appeared to differ little from thousands of hectares of surrounding countryside, so the reasons for their apparently restricted distribution are not clear. The fact that local people knew of their persistence at these sites relates in part to the popularity of the areas for hunting. Both lay close to permanent water sources and are situated alongside the main access road to the community.

We asked local people about the existence of other extant populations of *E. kintorei*, but no others were known in the area. This may be due to the reduced ability of local people to

**Table 1: Locality records for *Egernia kintorei* in Western Australia based on specimens held by museums and two sites of recent collection.**

| Collection date | Location | Latitude | Longitude | No. collected |
|---|---|---|---|---|
| 3/9/1891 | 95 km S of Barrow Range | 27°04'S | 127°25'E | 1; lectotype |
| c. 1930 | Near Godfreys Tank, Canning Stock Route | 20°14'S | 124°34'E | 4 |
| c. 1930 | Sturt Creek | 19°34'S | 127°40'E | 2 |
| 9/1963 | Skipper Knob | 26°56'S | 126°20'E | 1 |
| 1963 | near Warburton Mission | 26°08'S | 126°35'E | 1 |
| 9/11/1964 | Kathleen Valley | 27°24'S | 120°39'E | 1 |
| 1/3/1967 | 39 km ENE Laverton | 28°31'S | 122°45'E | 1 |
| 19/6/1997 | 45 km SE Karilywara, Gibson Desert | 24°55'S | 126°32'E | 3 |
| 15/12/1997 | 9 km SE Karilywara, Gibson Desert | 24°40'S | 126°20'E | 3 |

travel extensively to areas where hunting was once conducted (there were no four-wheel drive vehicles in the community and few roads are suitable for conventional vehicles), but it also suggests that populations of *E. kintorei* may be scattered and difficult to locate.

One habitat factor that might explain the scattered presence of *E. kintorei* was the diverse fire history of the sites. The burrow complexes occurred in small areas of hummock grassland that had escaped the most recent fire and were characterised by large hummocks and numerous *Eremophila leucophylla* shrubs. These patches were in proximity to areas regenerating after fire.

## Figure 1: Collection sites of *Egernia kintorei* in Western Australia.
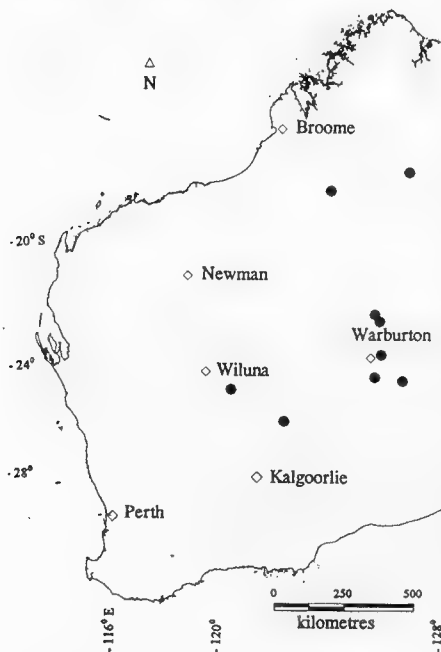


Following mild fires in this habitat, sand is blown around and accumulates against patches of unburnt vegetation. The removal of most of the biomass of spinifex (and hence competition for water), results in unburnt hummocks growing to much greater sizes.

These patches then provide *E. kintorei* with a good substrate for digging, and presumably food and insulation from weather extremes, until surrounding vegetation regenerates. Cursory examination of the faeces indicated that *Solanum centrale*, which occurred in nearby regenerating herbfield, was an important component of the diet at that time. This plant is highly dependent on disturbance, particularly fire (Latz, 1985).

## REPRODUCTIVE DATA

The three *E. kintorei* captured on December 15 1997 were taken to Perth and housed together in a large glass aquarium. They were kept on a sand substrate with a heat pad under one retreat (a lunch box with several PVC pipe entrances), a heat lamp on a timer to match daylight hours, an 18 W 'Sylvania Reptistar' fluorescent tube for UVA and UVB light and a 'cool' retreat box. Fruit (tomato, kiwi fruit, banana and apple), freshly killed mealworms and live cockroaches were provided for food. All were eaten readily.

Over the period of December 27-28 1997, the female gave birth to six live young. She weighed 209g prior to the births, with a snout-vent length (SVL) of 194 mm and a tail length of 202 mm. The young ranged in weight from 9.2-10.2 g (mean 9.8 g, standard deviation (SD) 0.34) with SVLs (mm) of 73-81 (mean 76.7, SD 3.50) and tail lengths (mm) of 70-79 (mean 74.5, SD 3.02). This translates to a total clutch mass of 58.9 g and a relative clutch mass of 39.2 % of maternal mass. The adult male was larger than the female, weighing 237 g at capture, with a SVL of 200 mm and a tail length of 209 mm.

Glenn Shea (unpublished) dissected 51 specimens of *E. kintorei* from the Australian Museum, the Museum of Victoria, the South Australian Museum, Northern Territory Museum and Art Gallery, and the Central Australian Wildlife Collection (Alice Springs). Unfortunately, most of the specimens he examined had no collection dates or were non-reproductive. Many had also been completely gutted. Nonetheless, it is possible to

glean some additional information about the species reproduction.

Males appear to mature at around 175 mm SVL, as indicated by the presence of turgid testes (Shea, unpublished). Testes in this state were observed in specimens collected in September and October, suggesting a spring or early summer mating period. Mature males collected in January had receding testes, but well-developed ductus deferens (Shea, unpublished). The presence of slightly enlarged ovarian follicles (2.5 mm diameter) in females over 166 mm SVL suggests this is the approximate size at maturity. Clutch size based on counts of enlarged ovarian follicles in the left and right ovary of four dissected females (SVL in brackets) were 5 (188 mm), 6 (182 mm), 6 (192 mm) and 7 (179 mm) (Shea, unpublished).

Two husbandry problems were encountered with the captive *E. kintorei*. Two individuals developed swollen feet due to bacterial infection following injury during digging. One juvenile that appeared to have been excluded from food and basking sites by the other lizards developed metabolic bone disease and was euthanased.

## COLOURATION AND EYE MORPHOLOGY

Neonates had a distinctive colouration, different to the adults. The dorsal surface was orange-red like the adults, but the flanks were a grey-blue colour with distinct yellow banding. This flank colour changed to creamy-grey with orange bands over a period of about a year, but never as strongly demarcated as described by Storr (1978).

The pupil of this species is circular under normal daylight conditions. However, when a strong torch is shone in the eye, the pupil contracts to a vertically elliptical form. The related species *Egernia striata* is the only Australian skink previously reported to have an elliptical pupil.

## ETHNO-ZOOLOGICAL INFORMATION

Pintupi people regard *E. kintorei* or 'tjakurra' as an excellent food. It was widely used in the past and still occasionally hunted by the older women. It is also an important spiritual totem and some local artists paint canvases celebrating its exploits. Tjakurra are located by searching for their characteristic burrows, each with its communal 'toilet', or by following its distinct tracks, which feature a continuous straight tail drag with small, round and alternate foot imprints. All informants stated that tjakurra were nocturnal and lived as small families ('one man, one women and some kids') in a burrow complex that they dug themselves. They stated that females produced up to 6 eggs, arranged in two lines of three on either side of the body. While no-one indicated that live birth occurred, this is not surprising given that such an observation without the benefit of captive animals is unlikely. A preference by tjakurra for burnt areas was recognised, particularly during the period 3-4 years after a fire.

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# A RECORD OF INTRASPECIFIC COMBAT IN FREE RANGING TASMANIAN TIGER SNAKES *NOTECHIS SCUTATUS* * (SERPENTES: ELAPIDAE).

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## INTRODUCTION

Agonistic male combat is widespread among Australian Pythonidae and Elapidae . and appears to exert selective pressure for larger male body size, relative to conspecific females, through increased mating success for the victors of combat bouts (Shine, 1978, 1994).

Australian elapid genera exhibiting male-male combat (*Austrelaps, Demansia, Drysdalia, Hemiaspis, Notechis, Oxyuranus, Pseudechis, Pseudonaja, Rhinoplocephalus, Suta*) are all characterised by males attaining greater body lengths than females. Shine (1994) predicts that all snake species in which males grow larger than females will prove to have agonistic interactions between reproductive males.

Male-male combat in Notechis has been occasionally recorded throughout large portions of the taxons range in recent years, but almost exclusively under captive conditions for populations in the Tasmanian region (Fearn, 1993; Firmage and Shine, 1996).

The authors present the first observations and photograph of free ranging male Tasmanian *N. scutatus* engaged in a prolonged combat bout.

## FIELD OBSERVATIONS

In the first week of February, 1999 the junior author encountered two male *N. scutatus* (both approximately 1200 mm body length) engaged in vigorous combat (Fig. 1) on open ground close to his residence in disturbed eucalypt forest at Bates Creek, Liffey at the foot of Dry's Bluff in the Western Tiers, northern Tasmania.

Neither snake was collected and sexed, however we are confident that both were males engaged in ritual combat because the postures were similar to those of other Australian elapids recorded in combat (Fleay, 1951; Shine & Allen, 1980; Shine et al., 1981; Shine, 1991; Covacevich et al., 1994), and in particular, closely resembled male-male combat in captive Bass Strait Island *N. scutatus* illustrated by Firmage and Shine (1996) and the mating behaviour of Tasmanian *N. scutatus* is a passive affair with little movement, no entwining of bodies and generally takes place in a concealed situation (Fearn, 1993).

The snakes were almost identical in length and bodily proportions (Fig. 1) and were engaged in combat for > 50 minutes. Combat behaviour consisted of each male attempting to press down the head of its opponent, either from directly above or from the side. Progressing forward in this manner produced intertwining of the posterior two thirds of the snakes bodies. On other occasions the snake's tails were intertwined and raised off the substrate (Fig. 1) as they attempted to out-manoeuvre each other. On occasions both males progressed forwards, intertwined, with head and forebody raised vertically off the substrate for a third of their length.

No other snakes were observed in the immediate vicinity but a third (differently coloured) specimen had been observed retreating beneath a nearby boulder on several occa-

* Due to the considerable morphological variation within the *Notechis scutatus* /*ater* complex and the fact that current taxonomy cannot be used to confidently assign individual specimens (particularly unbanded forms) to either species, the senior author believes all *Notechis* should be referred to as *scutatus* at this stage.

sions during the previous few days and may have been a female.

February is the period of most intense sexual activity in Tasmanian *N. scutatus* (Fearn, 1993).

## DISCUSSION

Intrasexual combat in Tasmanian and Bass Strait Island *N. scutatus* is a poorly understood and possibly rare phenomenon. For example, the senior author and three of his colleagues (I. Norton, B. Munday, C. Spencer) have a combined period > 100 years observing free ranging and captive Tasmanian *N. scutatus* without recording a single combat bout. Norton (pers. comm.) has maintained Tasmanian *N. scutatus* in large outdoor enclosures for 30 years and has bred hundreds of neonates in that time without observing any agonistic male behaviour.

In stark contrast, Firmage and Shine (1996) reported frequent male-male combat in large outdoor enclosures housing *N. scutatus* from several Bass Strait Island populations as well as among specimens from the Tasmanian mainland, however this may have been a result of maintaining very high densities of snakes in a relatively small area. Norton (in Fearn, 1993) observed male-male combat among Mt. Chappell Island *N. scutatus* but did so only once, in spite of numerous and extended field trips to that island which has a dense tiger snake population.

Only thoughtfully designed captive studies and/or extensive radiotelemetric field studies will begin to precisely quantify the factors that initiate intraspecific combat in Tasmanian *N. scutatus*. The senior author suspects that under natural conditions a prerequisite will be for two very evenly matched males (in length and mass) simultaneously converging on a sexually receptive female. This may, in part, address the apparent rarity of male-male combat observations for this taxon.

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Figure 1: Adult male Tasmanian *Notechis scutatus* engaged in ritual combat
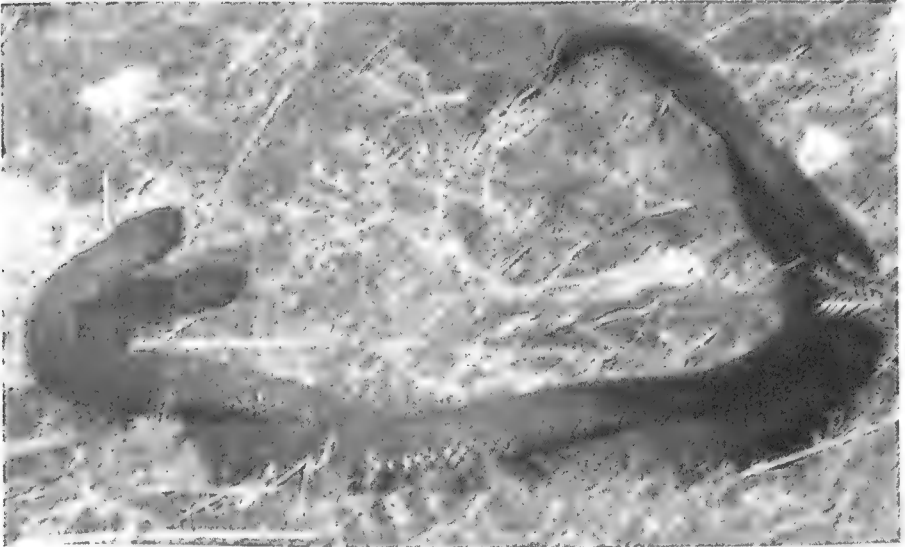
# HERPETOLOGICAL NOTES

## FOR COMFORT - ROTATE.

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The fact that many pythons adopt an inverted posture in the later stages before egg-laying has been noted for over half a century (Benedict 1932; Ross and Marzec 1990; Field 1990; Barker and Barker 1994; Greer 1997). However, the reason for this inversion has been subject to debate. Greer (1997) suggests that this position 'may serve to relieve the pressure on the egg mass exerted by the dorsum musculature and vertebral column'. The position is very common in all Australian pythons (see review in Greer 1997),

Two captive olive pythons (*Liasis olivaceus*), in excess of 2.5 metres and 6kg, and a large hybrid Children's python (*Antaresia stimsoni x A. maculosa*) (90cm and 480g) ovulated in early August 1998. The mid-body swelling was obvious in all snakes. Ovulation indicates fertilization of ova (Barker and Barker 1994). In the month prior to ovulation, all three pythons exhibited the inverted position. This behaviour obviously had nothing to do with the development of embryos, but suggests that the reason for the inverted position may be one of comfort.

During the year outside the breeding season, most *L. olivaceus* will use the inverted posture occasionally. Inversion does not appear confined to females, as male *L. olivaceus* are inverted as often as females throughout the non-breeding part of the year. Some animals that have recently eaten and are digesting food will invert during digestion; however, it is not confined to this period, as non-digesting *L. olivaceus* will also readily use an inverted posture. This behaviour is also common in both the Woma (*Aspidites ramsayi*) and blackheaded (*A. melanocephalus*) pythons (Greg Fyfe pers. comm). To date the small pythons of the *Antaresia* complex have not been noted to use an inverted posture when not reproductive, although this may be an artefact of observation. The inverted posture appears confined to the Boidae. It is obvious that it is not a feeding position. To strike from an inverted posture would be difficult. Because the inverted posture is very common throughout the year in *L olivaceus*, when fed and not fed for both sexes, I can only attribute this behaviour with one of comfort.

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# A NOTE ON A BICEPHALIC DEATH ADDER

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Although two-headed snakes have excited the media, particularly overseas (see Reptiles Magazine, June 1999: 28) there are almost no literature records of bicephalism in Australian species, although other abnormalities have been recorded (Mirtschin & Davis, 1982: 78). During my systematic audit of the Western Australian Museum reptile collection I encountered only a single neonate Dugite *Pseudonaja affinis* (R14150) with this condition. The record reported here is the first instance I have personally observed of bicephalism in an Australian species.

*Acanthophis wellsi* was described from the Pilbara region (Hoser, 1998). For the past five years I have maintained a 'typical' red male of this species with a hybrid female *A. pyrrhus/wellsi*. Both are illustrated as plates A and F in Aplin and Donnellan (1999:281). The female is derived from what appears to be a naturally occurring hybrid population between these two similar looking species from north-west W.A. (Aplin and Donnellan, 1999). Initial matings by the male yielded no results and I presumed this was attributed to female's hybrid nature or sterility, as I was following normal husbandry techniques of separating, cooling and reintroducing the male as the weather warmed up, both after the female had sloughed and otherwise.

In 1998 I maintained them together without separation and on 11 May 1999 twenty neonates were born including the bicephalic individual that weighed 4.0gm and measured 140mm total length. The mass and total length range of the others was 3.1-4.6gm and 138-165mm. Post-natal sloughs occurred between 20-23 May. Upon closer inspection of the bicephalic snake it appeared very weak and extremely lethargic with neither head gaining any obvious ascendancy. It experienced difficulty with sloughing which was done by hand and no tongue flickering was seen from either head. Unfortunately it died on the 26 May and was lodged (R137880) at the Western Australian Museum.

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# THE SPREAD OF AN EXOTIC WESTWARD: *HEMIDACTYLUS FRENATUS.*

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Cook (1990) outlined the movement of the exotic Asian House Gecko (*Hemidactylus frenatus*) south from Darwin down to Renner Springs, a distance of about 850km. He indicated that the range of the animal had extended west to Timber Creek, NT. This is a distance of nearly 600km from Darwin. Paul Horner (pers. comm.) from the Northern Territory Museum adds that it has been found as far south as Tea Tree, some 200km north of Alice Springs. We also found this gecko on buildings around Kununurra, 35km west of the NT border in 1992. In June 1996, we travelled to Broome, Western Australia and found a healthy population of the large native gecko (*Gehyra australis sp.*). In August 1998 we again travelled to Broome where we found a thriving population of *H. frenatus* at the Roebuck Bay Game Fishing clubrooms. At that time there were also *G. australis* on the building. This is a distance of 1900 km west of Darwin.

## REFERENCE

**Cook, R.A. 1990.** Range Extension of the Darwin House Gecko, *Hemidactylus frenatus.* Herpetofauna 20(2): 23-27.

# ERRATUM

Volume 30 number 2, December 2000 page 50

## "RECORDS OF THE WESTERN BROWN SNAKE *PSEUDONAJA NUCHALIS* (SERPENTES:ELAPIDAE) FROM TOWNSVILLE, NORTH EAST QUEENSLAND"

by Simon Fearn and Joseph Sambono Jnr

should have included the following photo in Figure 1. We extend our apologies to the authors.

**Figure 1. Pseudonaja nuchalis from Townsville QLD.**

# BOOK REVIEW

## A VETERINARY GUIDE TO THE PARASITES OF REPTILES.
## VOLUME 2. ARTHROPODS (EXCLUDING MITES).
By Susan M. Barnard and Lance A. Durden.
Published by Krieger Publishing Company,
PO Box 9542, Melbourne, Florida 32902, USA. 2000.
288pp. US$46.50 ISBN 0-89464-908-6

This is the second volume of an intended series on reptile parasites. The first volume, by Barnard and covering protozoa, appeared in 1994, and an inserted publisher's note in this volume suggests that later volumes in the series are intended to cover mites, trematodes, nematodes, acanthocephalids, pentastomids, leeches and pseudoparasites, although authors have not yet been contracted for the later volumes, suggesting that the complete series will have a long gestation.

With mites being excluded, the present volume on arthropod parasites mostly covers ticks (133 pages), with shorter chapters on flies (50 pages), reduviid bugs (3 pages) and fleas (1 page). The scope is intended to be world-wide, an important consideration for many northern hemisphere countries where there is extensive trade in exotic wild-caught reptiles, which could be carrying parasites from a variety of sources.

The major focus of the chapters on parasites is on identification. For flies, identification is to the level of genus, with keys to both adults and (later, in Chapter 5, which covers laboratory techniques) those larvae that parasitise reptiles. Generic accounts then list the species that have been recorded feeding on reptiles, and their geographic and host ranges, together with more general information on host location, life cycle, method of host acquisition, symptoms of parasitism, diagnosis and treatment. Most of the data in this chapter relates to North American flies, with the only Australian and New Zealand mentions being the curious statement that "larvae of *Calliphora stygia* cause myiasis in the green gecko, *Naultinus elegans*, in Australia", and the circumstantial evidence for a mosquito vector for the protozoan *Hepatozoon breinli* in Australian varanids.

The tick chapter similarly opens with a generic key only to adults. Within genera, descriptions of a few selected species (mostly American) are provided, followed by an annotated list of other species parasitising reptiles. A species key is provided only to the genus *Aponomma*, again only to adults. Although all Australian species parasitising reptiles are mentioned, illustrations are provided only for the three most recently described (and geographically restricted) species. Further, although the primary taxonomic literature on the Australian literature is listed, there is almost no mention of the extensive ecological studies on *Aponomma hydrosauri* and *Amblyomma limbatum* produced by Mike Bull and his team at Flinders University over the past 20 years. Readers familiar with the earlier volume on Australian ticks by Roberts (1970) will notice one nomenclatural change in the present volume. The species previously known as *Aponomma undatum* is here referred to as *Aponomma decorosum*, with *undatum* regarded as a synonym (p. 151). No justification is provided for this change (although the authors do refer earlier in the chapter to two references on the systematics of the genus, one an unpublished Ph.D. thesis), and it would appear to be unwarranted, as the name *undatum* antedates *decorosum* by over 90 years.

The volume closes with a chapter on "laboratory procedures for the herpetoculturist" (although most of the techniques described are more suited to a diagnostic laboratory), three appendices, covering parasiticides used for treating tick and fly infestations (most local keepers simply remove the individual ticks), products and suppliers (all U.S. based), a host-parasite list (with some Australian nomenclatural curiosities, including the northern tree snake as *Ahaetulla calligaster*, the eastern brown snake as *Demansia textilis*, and *Egernia striolata* as the spiny tree skink), and a glossary, reference list of 31 pages, and index.

In summary, for the local reader in Australia

and New Zealand, where no legal importation of exotics occurs outside Class A zoos, this book will be a disappointment, although it undoubtedly will be useful for American veterinarians unexpectedly called on to treat the range of exotic reptiles available there.

**REFERENCE:**

**Roberts, F.H.S. 1970.** Australian Ticks. C.S.I.R.O., Melbourne. 267pp.

Glenn M. Shea
Faculty of Veterinary Science
University of Sydney, NSW, 2006.

## BOOK REVIEW

### PYTHONS OF AUSTRALIA. A NATURAL HISTORY.
By Geordie Torr
Published by University of New South Wales Press, Sydney, NSW.1999.
103pp. $32.95 ISBN 0-86840-602-3 (Paperback)

Pythons are arguably one of the most popular group of snakes. This is probably due to their large size, unusual habits such as prey-contriction, male combat, and egg-brooding as well as their ease of keeping in captivity. And as for other Australian snakes, our understanding of pythons has grown enormously in the last 20 years. It was to be expected therefore that sooner or later the University of New South Wales Press' would commission a book on pythons for its Australian Natural History Series, a publishing project that focuses on popular species or groups of species that are either endemic to or widely represented in Australia. And Geordie Torr, a professional natural history writer and a professionally trained reptile biologist, has delivered a very nice addition to this worthwhile series with his "Pythons of Australia." This volume thus joins two others in the series with a reptile focus, one on goannas (Green and Green, 1999) and the other on sea snakes (Heatwole, 1999).

Briefly, the book is a very concise overview of the basic biology of the 13 species of pythons that occur in Australia. The information and discussion is in the context of the evolutionary history of the group, and never far below the surface is the underlying question of the evolutionary perspective: the adaptive significance of the trait being discussed. In addition to basic biology, there is also a "practical" section on captive care which should help the aspiring keeper get started.

Like the rest of the series, this volume is aimed at providing a concise overview for the beginning student or interested non-professional. Regrettably, the series does not allow for references in the text to the specific topics being discussed, the only references being some general ones at the end. Hence, unless one of these latter happens to touch on a specific topic, the interested reader is left to his own devices for finding further information.

Nonetheless, the book is perfect for the "student" developing an initial scientific interest in Australian pythons. From here it is just a short step into the technical literature and more detailed books on the topic.

### LITERATURE CITED

**Green, D. and B. Green. 1999.** Goannas: The Biology of Varanid Lizards. Second Edition. University of New South Wales Press, Sydney; 116 pp. Second Edition

**Heatwole, H. 1999.** Sea Snakes. University of New South Wales Press, Sydney; 148 pp. "Adapted" from the original 1987 edition.

Allen E. Greer
The Australian Museum
College St
Sydney, NSW 2000.

# BOOK REVIEW

## AMPHIBIANS AND REPTILES OF MADAGASCAR AND THE MASCARENE, SEY-CHELLES, AND COMORO ISLANDS.

Madagascar is the fourth largest island in the world and lies 400km to the east of Africa, separated from the African mainland by the Mozambique Channel. The island is recognised as one of the ecologically richest countries on the planet and a world conservation "hotspot", and boasts a mosaic of vastly different habitats and a copious array of endemic flora and fauna. Similarly, some of the other smaller Indian Ocean island groups such as the Mascarene, Seychelles and Comoro Islands are equally diverse and interesting. Despite this, and the knowledge that dramatic and rapid deforestation is driving many of these island species to extinction, relatively little research regarding the natural world of these areas has been published.

The current edition is a revised and translated version of the original German edition first published in 1995. This long awaited English translation incorporates some of the more recent taxonomic changes. The glossy-paged hardback commences with a brief overview of the various islands. The introduction is particularly well written, useful and very informative. Not only does it give good descriptions of the islands' vegetation and major fauna groups, it also covers the geographic history, regional climate and the prime activity periods for the main animal groups. This is good basic information for people wishing to visit the islands and see the wildlife.

In all, 240 species are covered including frogs, turtles and tortoises, chameleons, geckos, iguanas and agamas, skinks, and snakes. Individual species are listed alphabetically by Latin name, one per page and generally illustrated by large, full colour photographs. Most certainly, one of the best features of the book is the excellent photography, which simplifies the identification process. Each species account includes type locality, distribution, habitat,

biology and vivarium care. The inclusion of vivarium care is interesting and will, no doubt, be received with mixed feelings. It is particularly aimed at those wanting to keep these animals as pets, which curiously gives an "object" feel to the animals covered in this book. On the other hand, vivarium care can also assist those in the position of having to rescue and care for them, such as wildlife protection agencies and field researchers.

It is in the species profiles that you start to understand just how scant our knowledge of the herpetofauna of these islands really is. For those of us who grew up on the likes of Cogger's *Reptiles and Amphibians of Australia* basic information such as call descriptions, breeding seasons and status are sadly lacking for many of the species in this book. Although the authors do a fine job of compiling as much information as possible, the fact that the taxonomy of many genera remains to be adequately examined and that many species today are still rarely encountered makes comprehensive species accounts next to impossible.

While this book is an important reference for future researchers and Indian Ocean island travellers, it is lacking in a number of ways. As with any translated book, there is the occasional problem with wording (ie. "..eggs could be clearly seen through the stomach."). However, this does not detract greatly from the information presented and the translation is generally quite good. The species accounts would have greatly benefited from individual distribution maps; it is difficult and time consuming to continually refer to the map on page 8. To make matters more difficult, place names mentioned in species accounts (such as Antsalova, Nahampoana, Mandena, Beforona, Moramanga, Antsihanaka etc) are not included on any map so it is often difficult to identify the areas discussed. The authors also refer to

regions (eg. central highlands), but again no map or description of region boundaries is included.

The section "Checklist of Amphibians and Reptiles Found in the Areas Discussed" was confusing as there are many species included that cannot be found anywhere else in the book (of the 27 *Boophis* species listed only 7 are mentioned elsewhere). It is understandable that there may not be available information on these species. Nevertheless, it seems odd to introduce "new" species at toward the end of the book without explanation.

Overall, I consider the guide is a great book and a must if you are thinking of travelling to any of these biological fauna paradises. Having spent some time in Madagascar and the Mascarenes, I can agree whole-heartedly with the authors that the lack of field guides necessary to identify these amazing animals is both frustrating and painful. Despite its limitations this book goes a long way to easing that problem.

Michelle Christy
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University of Sydney, NSW, 2006.

# BOOK REVIEW

## TADPOLES: THE BIOLOGY OF ANURAN LARVA

After completing the writing of my Ph.D. thesis, I tentatively submitted it for examination. One of my examiners was Dr. Roy W. McDiarmid, a man with extensive amphibian knowledge, a great eye for detail, and a terrific sense of humour. So it was to my surprise and absolute delight that, three weeks after receiving Dr. McDiarmid's comments on my thesis, I was asked to review *Tadpoles*.

It is not very often that a book is published that fills a giant, gaping hole in the literature to the extent *Tadpoles* has done. In short, it is a magnificent and extremely indispensable text. When reading through the 348 pages of text and 88 pages of references (around 3000 in all), the word "comprehensive" was always prominent in my mind. The book provides an important overview of tadpoles including a review of historical research activities in terms of origins and evolution. It examines most aspects of tadpole biology from research techniques to evolution, anatomy, physiology and ecology, prepared in 12 discrete chapters. Each chapter is detailed and technical while still remaining relatively easy to read. In those instances where you may feel a little bogged down by scientific jargon, an extensive and well-explained glossary can be found preceding the index.

Each chapter describes methods and results from selected papers and follows up with a general discussion and overview. Strong emphasis is given to physiology and anatomy, but evolution and behaviour are also well covered. If there is any fault to be found in this book, it is that specific experimental protocols are generally discussed in, what I consider, unneccessary detail. Such specific information can usually be gleaned from the original papers rather than be included in this textbook.

The editors are quick to point out that even though this book is indeed comprehensive, it does not contain all there is to know about tad-poles. The lack of information in some areas of study is a theme repeated throughout the tome, weaving its way through the chapters like a silver thread. They suggest that the extent of morphological diversity between species and at specific development stages further complicates matters, and as a result a thorough understanding of tadpole biology almost impossible to achieve. However, the holes in the current knowledge base do not detract from the extent to which this book has filled in previously large gaps in our knowledge and brought important tadpole research to our attention. In fact, they simply point out areas in which future research can be directed.

It should be stressed that this really is a reference book, aimed at those studying or teaching amphibian biology, and is an ideal starting point for anyone wishing to delve more deeply into the world of amphibian biology. It is the only fully comprehensive review of larval anuran biology written to date and is a "must have" addition to any serious herpetologist's library. Furthermore, the literature review and reference list is exhaustive and it is almost worth owning the book for these sections alone. The scientific nature of the book by no way precludes non-scientists or researchers from gaining much valuable information from *Tadpoles*. On the contrary, the use of sections, subsections and high quality illustrations make navigation and extraction of information readily available, and students of all ages will find it an extremely valuable reference.

In summary I have no doubt *Tadpoles* will be greeted with open arms by those who have lamented the lack of such a book in the past, and will achieve the editor's aim of providing a good, solid base on which future published research can grow.

Michelle Christy
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# NOTES TO CONTRIBUTORS

*Herpetofauna* publishes articles on any aspect of reptiles and amphibians. Articles are invited from interested authors particularly non-professional herpetologists and keepers. Priority is given to articles reporting field work, observations in the field and captive husbandry and breeding.

All material must be original and must not have been published elsewhere.

## PUBLICATION POLICY

Authors are responsible for the accuracy of the information presented in any submitted article. Current taxonomic combinations should be used unless the article is itself of a taxonomic nature proposing new combinations or describing new species.

Original illustrations will be returned to the author, if requested, after publication.

## SUBMISSION OF MANUSCRIPT

Two copies of the article (including any illustrations) should be submitted. Typewrite or handwrite (neatly) your manuscript in double spacing with a 25mm free margin all round on A4 size paper. Number the pages. Number the illustrations as Figure 1 etc., Table 1 etc., or Map 1 etc., and include a caption with each one. Either underline or italicise scientific names. Use each scientific name in full the first time, (eg *Delma australis*), subsequently it can be shortened (*D. australis*). Include a common name for each species.

The metric system should be used for measurements.

Place the authors name and address under the title.

Latitude and longitude of any localities mentioned should be indicated.

Use the Concise Oxford Dictionary for spelling checks.

Photographs – black and white prints or colour slides are acceptable.

Use a recent issue of Herpetofauna as a style guide.

A computer disc may be submitted instead of hard copy but this should not be done until after the manuscript has been reviewed and the referees' comments incorporated. Computer discs must be HD 1.44 mb 3.5" in Word for Windows; Wordperfect; Macintosh or ASCII. Any disc must also be accompanied by hard copy.

Articles should not exceed 12 typed double spaced pages in length, including any illustrations.

## REFERENCES

Any references made to other published material must be cited in the text, giving the author, year of publication and the page numbers if necessary. At the end of the article a full reference list should be given in alphabetical order. (See this journal).

Manuscripts will be reviewed by up to three referees and acceptance will be decided by an editorial committee. Minor changes suggested by the referees will be incorporated into the article and proofs sent to the senior author for approval.

Significant changes will require the article to be revised and a fresh manuscript submitted.

## REPRINTS

The senior author will receive 25 reprints of the article free of charge.

A red colour morph Death Adder from Magnetic Island.



A grey colour morph Death Adder from Magnetic Island. See paper on page 19.